SOLAR SCIENCE PROJECTS

For a Cleaner Environment

by D. S. HALACY, JR.

(Formerly *Fun with the Sun*)

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INTRODUCTION

The great energy crisis has already taught us two important lessons. First, it *is* possible to run short of those fuels we have relied on for generations. Second, we pay an almost unbelievable price when we do run short. The long lines of motorists vainly trying to find gasoline, the cold homes, and dimly lit streets change quickly from nuisances to dreary new ways of life. Even worse are the thousands of jobs lost as energy supplies fail. Bad as the situation seems to us, other countries suffer far greater hardship and face bleaker futures.

There is a third lesson, a brighter lesson, that we can also learn if we are wise. That silver lining among the black clouds is the use of an alternative source of energy. It is the promise of solar energy. As the projects in this book will show you, the sun offers not just clean, safe energy but energy that will last as long as the sun itself. Taking that energy is up to us.

D. S. Halacy, Jr.

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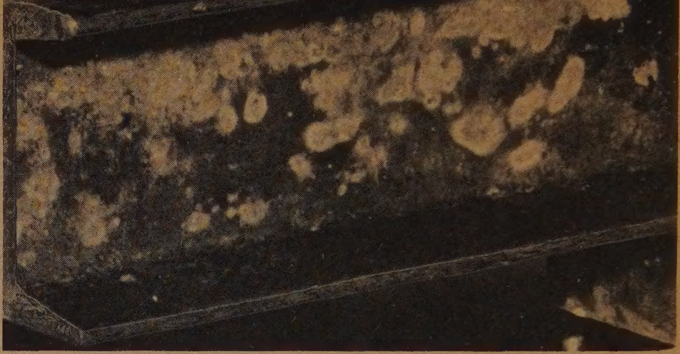
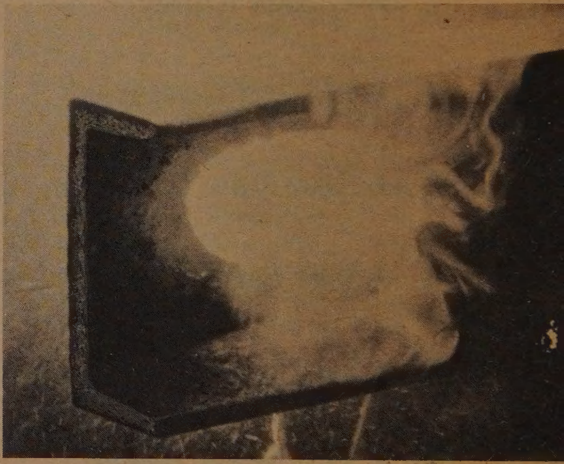
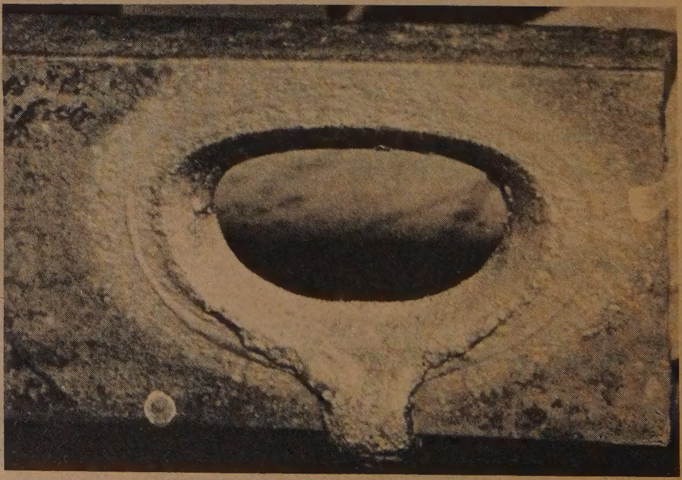


Iron "I-beam" is set in solar furnace for test.



Concentrated ray burns through tough metal.

Four-inch hole illustrates focal power of solar furnace.



U.S. ARMY

1 Why Solar Energy?

ONE OF THE most pressing problems facing our world is the increasing pollution of our environment — a dirtying of the air we breathe to the point of causing illness and death. Pollution is caused by burning the "fossil" fuels of coal, oil, and gas, as well as the burning of vegetation such as wood, that pollutes our atmosphere so dangerously. It is ironic that the sun, which has given us the heritage of fuel we use for energy in our power-hungry world, showers us each three days with as much energy as is stored in *all* our fossil fuels!

The sun, with an internal temperature estimated to be as high as 30 million degrees Fahrenheit, consumes about four million tons of hydrogen each second. The hydrogen is converted by the process of fusion to helium, and great quantities of energy are produced as well. Even at our distance of 93 million miles from the sun, Earth receives about 85 *trillion* kilowatts of constant

power in the form of solar radiation or sunlight. In the United States alone, this is equivalent to about 1,150 billion tons of coal a year. Unlike coal, however, sunshine is energy in its purest form.

It is a tragedy that we do not work diligently to make more use of this solar energy to heat our homes, to distill water, and to provide energy for driving our power plants and our many transportation vehicles.

There are many reasons for the failure of solar energy to emerge as the clean, safe source of power it promises. The tendency of mankind to continue in the old traditional ruts is one reason. Lack of research and of applied solar science are other reasons. Yet a century ago, mine owners in the high mountains of Chile were providing fresh water for their workers with a huge solar still. More than 50 years ago a large solar power plant pumped water in Egypt. Today there are a few fairly large solar stills in various parts of the world providing fresh water — another much-needed commodity in this age of water crises.

A few years ago, the development of the solar battery gave hope to solar enthusiasts that the day of wide and useful application of solar energy was near. But only in a few limited areas such as space satellites has this marvelous converter of sunshine to electricity been put to practical use.

Solar energy is a fact of life, a vital fact that gives us our very existence. It is safe energy that lights our way, gives us our food and fresh water, our wind- and waterpower, and the promise of clean and abundant power on a much broader scale if we will but harness

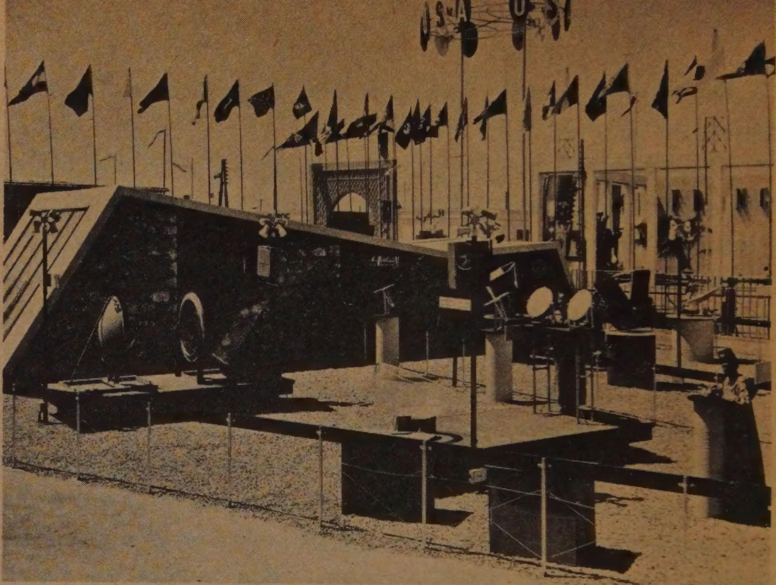
it. But like the camel led to water, it is hard to make us drink.

Apparently it is going to be up to a new generation, the science-minded young people of today, who are not rigidly tied to the old and comfortable power-production methods — and the belief that it is so easy to burn dirty fuels, that we shouldn't even bother looking for new and better methods.

Here's your invitation to the fun of seven projects that put solar energy to work in a variety of simple, useful ways. In the chapters that follow there are plans for solar stoves, a radio, a water heater, a furnace, and other projects that will give the reader who works on them ample reward for the time spent. But before we begin to assemble a solar oven, or a radio powered by a sun battery, let's take a brief look at this power source called solar energy to see why it is such a fascinating and challenging subject.

The so-called "solar belt" extends from the equator to the fortieth parallels of latitude, which means that solar devices will work in most of the populated areas of the world. Of course, the more sunshine, the more efficient the device; and the sun high overhead is stronger than when it is low on the horizon. But even as far north as Montreal, a solar home has proved its worth. Chances are that unless you are a resident of Little America, there will be enough sunlight available to operate the project of your choice.

So great are the long-range possibilities of solar energy that scientists have called the sun our "peaceful H-bomb." Fortunately, to build solar devices we needn't



SOLAR ENERGY SOCIETY

This solar fair in Casablanca demonstrated many solar projects, including a sunheated home, cookers and furnaces.

be skilled engineers and millionaires as well, as we would have to be to construct a nuclear machine. As a matter of fact, each of the projects presented is within the mechanical ability of nearly anyone and won't strain even the most modest of pocketbooks.

Using Solar Heat

High in the Pyrénées Mountains of Southern France is the Mont Louis solar furnace. Constructed just after World War II, this huge installation is 35 feet in diameter, and is used in high-temperature research. It develops temperatures of thousands of degrees and smelts metals and other materials for industry. Furnaces of similar size are operated by the U. S. Army Quartermaster Corps at

Natick, Massachusetts, and by scientists in Japan. At Odeillo, France, the world's largest solar furnace towers nine stories tall and will soon be in operation.

A fully equipped solar furnace five feet in diameter and developing 6,000 degrees Fahrenheit, suitable for research or industrial use, costs about $8,000. Larger ones, like that of the Army, cost far more of course. Few of us could afford even the "little" five-foot model, but we can build a solar furnace with a lens 14 inches in diameter capable of producing a temperature of 2,000 degrees Fahrenheit or more. That heat will melt a number of metals and can be used for soldering, light brazing, tempering, and annealing. An excellent use for the furnace is that of firing enameled jewelry.

Commercially produced solar stoves have been marketed for about $30. They were well worth the money, since they fold compactly for taking along on picnics and camping trips. Our homemade stove is much homelier and doesn't have the advantage of portability. To offset these disadvantages, this one is much less expensive and quite easy to build. Costing about five dollars, it is made from cardboard and aluminum foil. Yet it will cook eight hot dogs in ten minutes or boil a quart of water in a little over half an hour, with no time lost in getting the fire going!

When you tire of steak, hotcakes, and so forth, there is a solar oven to take care of another kind of cookery. This project is made of sheet metal and is faced with window glass. A real oven in every sense of the word, it uses the "greenhouse" principle to trap the sun's heat.

Our oven developed 350 degrees in mid-January, and will bake bread, casseroles, meat dishes, and even pies. A bit more expensive than the solar stove, its materials cost ten or twelve dollars.

Solar hot-water heaters have been in existence for some time, but today they are better designed than they once were. And swimming pool owners can heat their pools in this way for winter swimming. The water heater we will build provides a modest supply of hot water for camp or cabin. It uses principles familiar to engineers and architects in the home heating and cooling field — those of conduction and convection, and a handy phenomenon called *thermosyphoning*.

Large solar stills, producing thousands of gallons of water daily, are operating in Greece and in Australia. Solar scientists suggest the use of sea water for irrigation and even domestic use in areas of water scarcity. Lands like Israel and our own southwestern deserts would profit by successful application of these ideas.

Our solar still has a collection area of about four square feet. Distillation of sea water — to alleviate shortages caused by dwindling supply and increasing population — will require acres of surface, together with special plastic materials with an efficiency of light transmission higher than that of materials now available. In principle, however, the small model we will build is much the same as the pilot plants already built and the full-scale installations to come. It will distill salty or otherwise unfit water, making it suitable for drinking, for use in batteries, steam irons, and so forth, or for experimental purposes.

Solar Electricity

The use of silicon cells, or some other type of "solar battery" to convert sunshine into electricity, is an example of the great strides being made in the solar energy field. Twenty years ago the sun battery wasn't much more than a hopeful gleam in the eyes of research scientists. Today radio receivers are picking up the signals generated by silicon cells carried in many satellites.

Getting back to Earth, sun-powered radios have been on the market for several years, playing on sunlight and designed to last literally forever. They operate in artificial light too, and some of them can even store up sunlight energy during the day for evening use. The accomplishments of the sun battery make it the most dramatic use of solar energy. Able to tap the vast reservoir of "free" power the sun beams at us, the sun battery is assured an important part in man's just beginning conquest of space.

Building and operating a solar radio will obviously give you only a glimpse of the many and varied possibilities of the solar cell. For example, electricity is a convenient way of using power and of storing it too. Sun batteries thus offer a practical 24-hour source of energy when coupled with proper storage batteries. The efficiency of commercial solar cells now available and in use is about 11 per cent. Laboratory results have run as high as 14 per cent; the theoretical maximum is 22 per cent. Even at the 11 per cent figure, a roof of solar batteries could easily power the most mechanized home with only a week of clear weather a month!

The drawback, of course, is the present price of solar cells. The rooftop installation we talked about for electrifying a home would involve an outlay of many thousands of dollars and thus would be prohibitive except for millionaire solar enthusiasts. It is hoped that since the silicon used in the cells is one of the most plentiful elements on Earth, the price will be drastically reduced in the future. In the meantime, don't despair. The cells we'll need for our solar radio cost only a few dollars and should last many, many years with care.

Power from the Sun

Early techniques for using the sun to drive engines were crude by our standards, but pioneer solar engineers like John Ericsson built hot-air engines almost a hundred years ago. The output of these primitive machines was low, but the challenge of "free" energy was a strong one. Each square yard of the Earth's surface receives about 1,000 watts of power during sunlight hours. Some simple reflectors convert about half of this to useful heat, and when we consider that one horsepower is roughly 700 watts, the possibilities are more intriguing.

Lake Mead, back of Boulder Dam, receives more sun energy than its waters develop as they cascade down to the huge hydroelectric generators! At present, this energy is wasted, but when we learn how to make use of such "low-grade" sun power we will never again need to worry about running out of fuel.

Solar engines, and pumps have been produced. Huge sun-heated steam plants have been proposed. What

will finally be the most economical solar power plant may depend on the findings of the new generation of scientists. Whatever form it takes, it will use the same energy as our simple solar-battery-operated electric motor.

Not nearly so spectacular, but perhaps of more importance in the long run, are the solar homes and sun-heated buildings that are being developed in increasing numbers. Heat is of course a logical thing to take from the sun, but engineers plan to take just the opposite as well. Refrigeration systems powered by the sun have shown promise in tests, and solar plants have produced ice in sizable quantities.

In addition to the sun projects presented here, other solar devices are interesting and thought-provoking: the sundial, the earliest form of solar clock, and the radiometer, a sun motor in its simplest form yet suggesting one of the most fantastic space-traveling concepts that has been considered.

All of our projects, you will find, are easy ones. Although they require no special skills or expensive tools, and their cost is small, they demonstrate most convincingly the applications of solar science. In building those of your choice you may acquire the curiosity to delve deeper into the fields of thermodynamics, optics, electronics, and mechanics. This is the way it should be. Good luck, and get busy having fun with the sun!

2 A Reflector Cooker

A STOVE made of paper sounds about as practical as a pitcher carved from ice, but that is going to be our first project. Constructed almost entirely from cardboard, this reflector cooker will broil steaks, grill hot dogs, fry bacon and eggs, and make hotcakes and coffee. It will also heat the water for doing the dishes. All that is necessary is clear weather, because this stove cooks with sunshine!

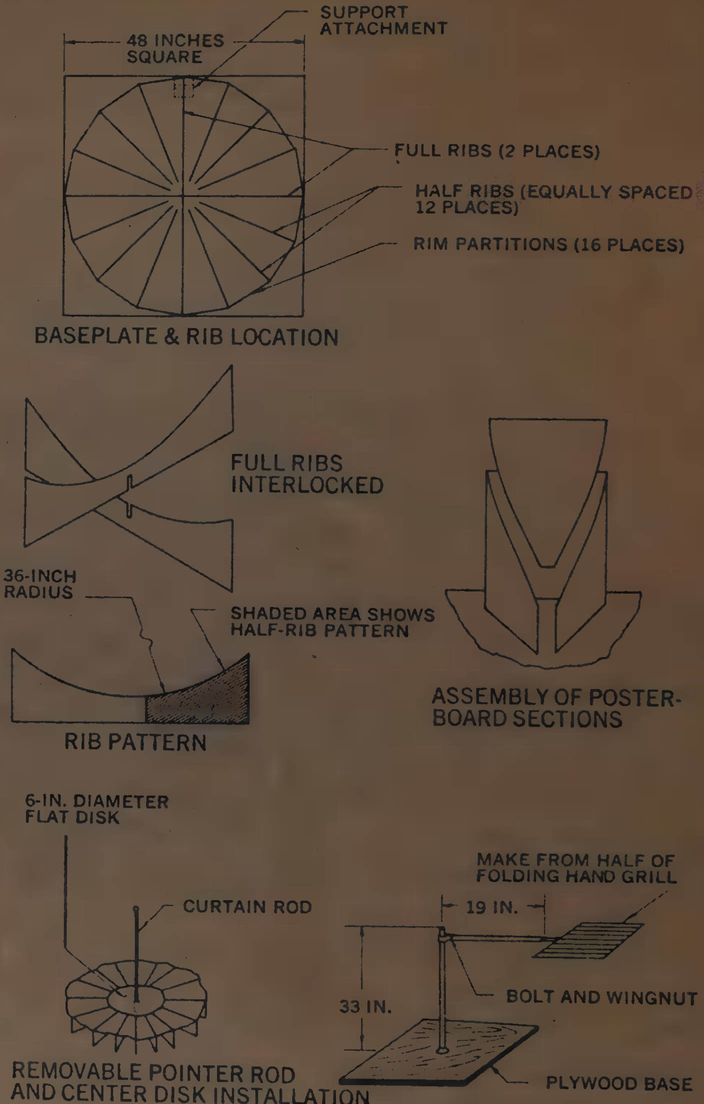
Stop to think about it for a minute and you'll remember that every time we cook – be it with gas, electricity, or charcoal – we indirectly use the sun's energy, which has been stored up and reconverted to heat. Basically, then, our solar stove's fuel is nothing really new. Even the use of direct sun heat for cooking goes back many years. Sun-dried foods have long been eaten, and crude solar

stoves were built a century ago. Besides, who hasn't heard of cooking an egg on the sidewalk on a really hot day?

In recent years, however, many advances have been made in the design of solar cookers. Today there are commercial models on the market that are fine for campers or for patio use. One umbrella-like design folds up for easy carrying and storage and also provides an answer for the skeptic who wants to know what you do when it rains! Such a cooker is just the thing for trips. If you are dubious about how well the sun can cook a meal, or if you don't have the cash to buy a ready-made stove, get busy and build the one described on the following pages. At most, it will cost ten dollars. If you use discarded cartons and other salvage material, the outlay will be only a fraction of that.

Materials

Cardboard – as required
Poster board – two sheets
Aluminum foil – one roll
Plywood – one piece, 18 by 24 inches
3/4-inch aluminum tubing – approximately 64 inches
3/4-inch mounting flange – one
Grill – one
Curtain rod – one
Broomstick – four feet
Clothesline – one foot
Glue – as required
Masking tape – as required
3/16-by-1-inch bolt with wing nut – one set



REFLECTOR SOLAR COOKER

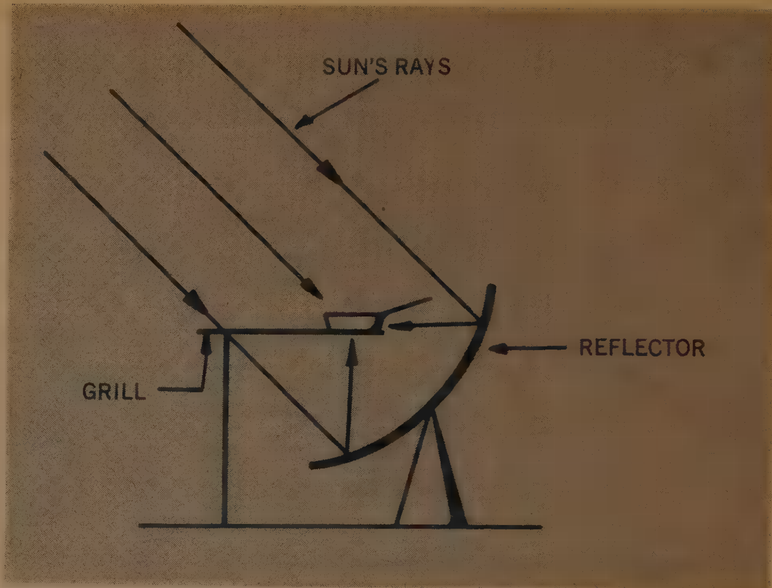
The reflector framework is cut from fiberboard, approximately 3/16 inch thick, the kind large cartons are made from. Some poster board and aluminum foil will complete the cooker itself. A grill (for hot dogs, hamburgers, or pans) is made from plywood, some tubing, and an inexpensive hand grill that costs about 50 cents.

Study the plans first to get the over-all picture, and to see how much new material will be needed. If you want to buy new fiberboard, two sheets 4 by 8 feet will be plenty. These cost about 80 cents each at a box factory or supply house. The other items will be easy to find. Get all the materials ready and then begin construction. An eager beaver can do the job in a day or so and begin sampling outdoor cooking à la sun right away.

First, cut a base piece 4 feet square from the 3/16-inch cardboard. We will mark the layout of the reflector ribs right on this base. With a pencil and a piece of string, draw a 48-inch diameter circle. This is the size our finished cooker will be. Next draw two lines through the center of the base, perpendicular to each other as shown on the plans. These mark the location of the main ribs, which we will make next.

A word about the principle of our reflector cooker will be helpful before we proceed any farther. The sun stove simply focuses all the sun's rays that strike its surface onto the bottom of the grill. Even on a clear winter day the 12 square feet of area in our cooker collects a lot of "warmth," which when shrunk into the 1-foot area at the grill becomes concentrated "heat."

The giant solar furnaces we talked of in the first chap-



Principle of the reflector cooker.

ter use curved reflectors too. They generate thousands of degrees of heat at their focal points, using the same principle. To do this they must be very accurately made and of parabolic shape. This specially shaped curve reflects all the ray's onto one tiny spot and gives the furnace a concentration ratio of many thousands to one. Obviously we don't want such high temperatures, for they would melt our pans!

Our reflector will use a radius of 36 inches instead of a true parabolic curve. This results in a larger spot at the focal point. Besides this, we will use a number of wedge-shaped sections instead of one bowl-shaped reflector. Thus our focal spot will be roughly the size of the cooking pan, which is just what we want.

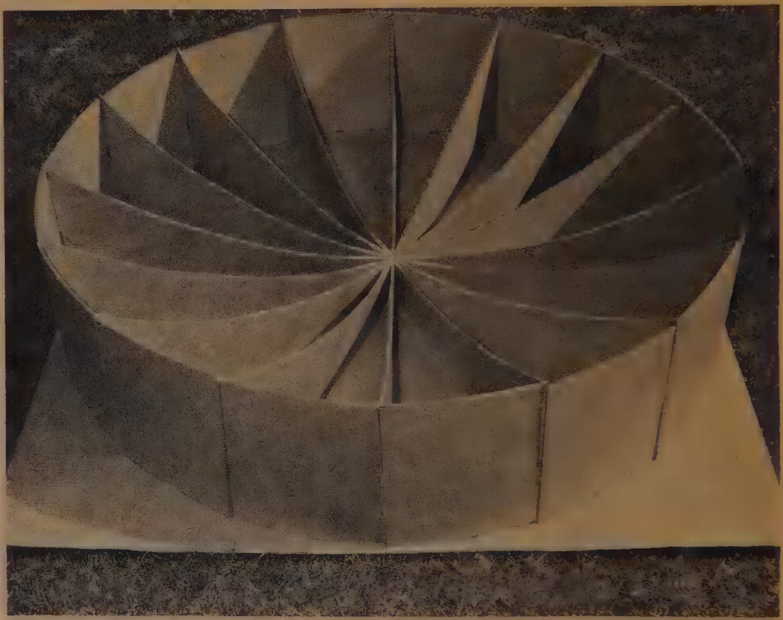
Now that we know the why of what we are doing, let's draw two main ribs as shown on the plans. Cut these carefully, using a sharp linoleum knife, pocketknife, or modeler's razor knife. Be sure to plan ahead so as not to waste material as you lay out the ribs. Each of the main ribs has a notch at the center. Notice that one is on the top and one on the bottom so that they will interlock.

Using a full rib as a pattern, mark out 12 half ribs as shown on the plans. Before cutting these, cement the full ribs to the base plate on the lines previously drawn. Model airplane glue or a good household cement will work well. While the parts are drying, cut out the remaining ribs.

Three half ribs fit between each quarter section of the circle. Glue these in place, lining up the end of each one with the circle we drew on the base plate. While they are drying, cut the rectangular filler pieces of cardboard. As the plans show, these fit between the outer tips of the ribs to complete the framework.

When the framework is thoroughly dry, we are ready to put on the wedge-shaped pieces of poster board. Since these form the curve that will reflect the sun's rays, we use poster board that is thin enough to bend easily, yet has sufficient body to hold the proper shape. Lighter cardboard would have a tendency to ripple and wave.

By means of cut-and-try methods, trim one piece of poster board so that it covers the space between two ribs, with about 1/8-inch overlap all around. Do not cement this in place yet; it will be our pattern for 15 more pieces. Cut them carefully, making sure they will cover any of



Assembled framework of reflector.

the spaces between ribs. (In spite of care, there may be slight inaccuracies in the framework.) It is better to have the poster-board pieces a bit too large than too small.

With all the pieces cut we can now begin to cement them in place. Since butting the joints smoothly against each other would be difficult, we will glue eight pieces in alternate spaces first. Spread glue along the tops of two ribs and the intervening filler piece, then lay the poster-board wedge in place and carefully press down so that it touches the ribs at all points. The glue will dry well enough in a minute or two so that you can go on to the next piece. Don't forget to leave every other section open.

Now we can cover the open spaces with our remaining eight pieces of poster board. These will of course lap over the edges of the pieces already glued in place, thus making a strong joint. If you run into difficulty at the center where all the points come together, simply trim them off an inch or two. The hole left can later be covered with a separate piece of poster board.

For added strength, seal all the joints with masking tape as shown in the photograph. While this isn't absolutely necessary, it will make a sturdier cooker. The reflector is now ready for application of the aluminum foil that will give it the mirror-like finish we need to collect heat for cooking.

Reflector ready for aluminum foil covering.

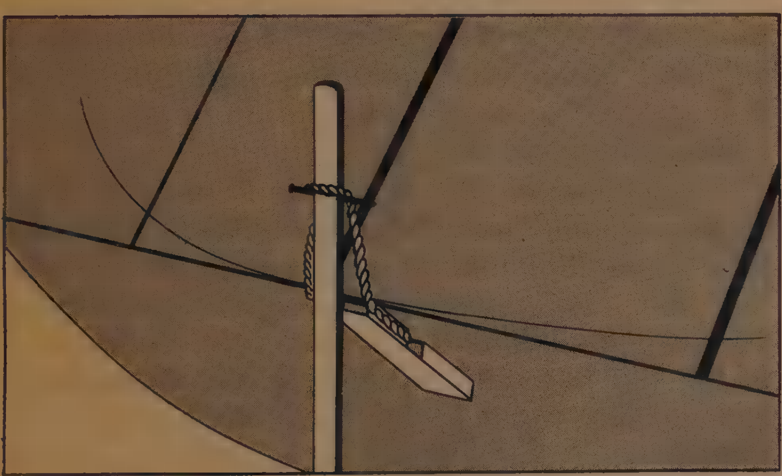
Cut out 16 pieces of smooth-surfaced aluminum foil — the kind used in the kitchen for wrapping food. These should be slightly larger than the poster-board pieces to assure complete coverage of the reflector surface. Use rubber cement to stick the foil to the poster board, and be sure to have the shiny side up. Work carefully and try to keep the foil smooth, but don't worry if the finished job is not perfect. The cooker shown in the illustrations has a few ripples but works well anyway.

We will now install a marker for the focal point of the reflector so that we will know where to place the grill for the fastest cooking. This is simply a small, inexpensive curtain rod of the type used on kitchen doors. It consists of two tubes, one fitted inside the other. We will cut a short length of the larger tube and insert it into a hole punched in the center of the reflector. Better still, use a drill the same size as the tube or slightly smaller to give a snug fit. Now cement the tube in place.

The smaller tube will fit into this "holder" and can be removed for easier handling when not needed. As we mentioned before, the focal distance from our reflector is the proper place for mounting our grill. With a spherical reflector the focal length is half the radius, or in this case 18 inches. As a double check, aim the reflector at the sun and adjust the tilt until there is no shadow visible from the pointer rod. Then hold a piece of wrapping paper with a small hole punched in it right at the tip of the pointer. Move the paper toward the reflector and then away from it until the smallest spot is observed on the paper. This is the actual focal point, and our pointer rod should be cut to this length.

Cut out two squares and one rectangle of cardboard as shown by the dotted lines on the plans and cement them to the back of the cardboard base. The squares go first, and then the rectangle. After these are well dried, run a short length of clothesline through the slot and tie the ends in a square knot. Drill holes through a 48-inch length of 1-inch dowel (broomstick or tubing), spacing the holes about an inch apart halfway down the dowel. Insert a nail to engage the loop of clothesline. We can now set up our reflector so that it will stand alone.

To make the grill, first cut a plywood base 18 by 24 inches. Any thickness from 1/2 to 1 inch will do. Mark the center and install a mounting flange for the 3/4-inch aluminum-tubing vertical support, which is 40 inches long. The adjustable arm is also aluminum tubing, 24 inches long. Flatten one end as shown and bend around a piece of pipe or a broomstick to make the collar, which



Attachment of adjustable support.

fits over the vertical support. Drill a 3/16-inch hole as shown and insert a bolt and a wing nut. The other end of the adjustable arm may now be flattened. Be careful to keep the flat area at right angles to the collar so that the grill will be horizontal when installed. Slide the grill in place and the solar cooker is complete.

Now that the work is done the fun starts. Positioning the reflector is simple if you follow these directions. Stand behind it and face it right at the sun. Now tilt it back until the shadow of the pointer rod vanishes as it did when we checked for focal length. This means that the reflector is aimed perfectly and that all the sun's rays will be bounced right where we want them.

Holding the reflector in this position, slip the dowel or broomstick through the rope loop and put the nail through the hole just below the loop. With the reflector on its own feet you can now put the grill in place. Loosen the wing nut on the adjustable arm and move it up or down until the grill rests just above the tip of the pointer rod. As a double check, pass your hand quickly just above the grill. It should be hot, ready for you to start cooking.

The grill surface itself is fine for cooking hot dogs, burgers, or steak. Grease will drip on to the reflector but will not harm it. For bacon and eggs, hotcakes, and the like, place a skillet on the griddle. And if you like your steaks seared quickly to keep in the juice, use the skillet for them too. By putting it on the grill a few minutes early you can store up extra heat that will cook the steak more rapidly.

SOLAR ENERGY SOCIETY

Solar stoves designed by Dr. Adnan Tarcici, U.N. delegate from Lebanon, shown at left. Stoves fold for convenient carrying or storage.

Water for coffee, tea, or just for dishwashing can be heated in a kettle or pot. To get the maximum efficiency from your solar cooker, use blackened utensils; however, just about any kind of utensil works satisfactorily. For variety try using a pressure cooker.

Because the sun moves across the sky, the position of the reflector will be different as time passes. In the early morning or late afternoon it will be nearly vertical, while at noon you will have to place it practically flat on the

ground. That's why we drilled so many holes in the support rod. If you plan to boil beans or make stew, occasional adjustment of the reflector will be required to keep the hot spot where it will do the most good. The shadow from our pointer rod is the thing to watch. For bacon and eggs, hot dogs, and even steak, one setting will usually do the trick.

After cooking your meal and washing the dishes, remove the grill from the aluminum tube and clean it, too. Then wipe off the reflector surface with a paper towel or damp cloth and that's all there is to the job of solar cooking.

Of course, solar stoves won't take the place of other kinds of cooking all the time. When the sun goes down you had better be through cooking, and on a rainy day the reflector is not much use except maybe to crawl under to keep dry! But properly used in clear weather it will amaze the most skeptical observer. Here are a few of the advantages of solar cooking.

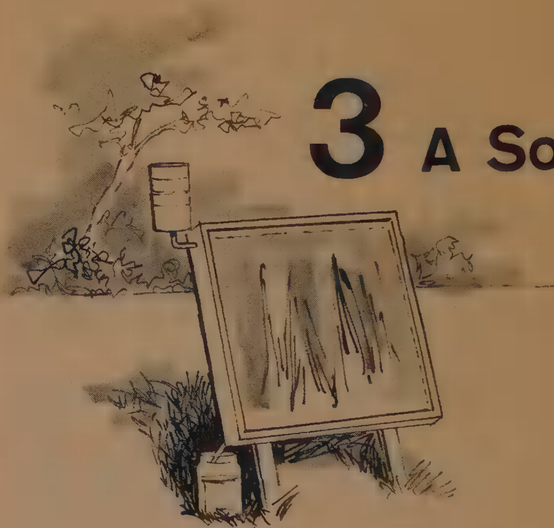
As you discovered when you held your hand close to the focal point, there is no warming-up period with a solar stove – it is hot right away! By the time the fellow with the charcoal brazier gets a good bed of coals you will be doing the dishes. Besides, he paid for his fuel while yours was free for the taking. And solar energy is available any place the sun shines – mountains, desert, beach, or your own back yard.

At first the reflection from your cooker might be bothersome, and a pair of sunglasses will be handy. After practicing a while you'll find out where to stand so there

isn't any glare, and by then you will have noticed how nice it is not to have your eyes full of smoke. Solar cooking is cool cooking, too, because the heat goes into the food on the grill and doesn't roast the person doing the cooking as well.

You won't need matches to get your cooker going, and there's no danger of setting anything on fire either. Lastly, there are no ashes or soot to contend with. And if someone complains about the lack of that charcoal or hickory taste, provide him with a bottle of liquid smoke.

Seriously, you will have a lot of fun cooking with sunshine. It's safe, it's clean, and it's free. Chances are you'll like it enough to want a portable cooker for the next camping trip. That way you won't be tied down to a fireplace and the bother that goes with it. So save up for a commercial folding cooker, or you might even put your ingenuity to work and make a version of the cardboard stove that is portable.



3 A Solar Still

IN 1872, mine owners in the high country of Chile were faced with the problem of providing drinking water for their workers. The only available supply was unfit to drink, and so a means of purifying it had to be found. Amazingly, the solution was a sun-operated distilling plant in which a large area of glassed-over wooden frames evaporated the contaminated water, recondensed it, and thus produced as much as 6,000 gallons of fresh water in a day!

This solar still used no fuel or power except that from the sun's rays and was thus able to provide pure water at a cost unmatched by any other means of distillation. Oddly, the method was forgotten in the intervening years and fuel-operated stills were used whenever it was necessary to convert salty or otherwise undrinkable water.

Not until World War II were solar stills used again except by experimenters. Fliers forced down at sea needed a source of supply of drinking water until they could be rescued. Dr. Maria Telkes developed an inexpensive, lightweight plastic still that could be included even in the one-man life rafts and that would provide a quart of fresh water a day.

Since that time Dr. Telkes and other scientists have worked with solar stills of various sizes. Our government's Department of the Interior is interested in the method, and plans have been made for large seacoast installations to purify salt water for drinking and irrigation. In some designs no pumps would be needed because the sea itself would fill the condensing tanks at high tide.

At present it is felt that the cost of such a system would be too high, even considering that cost of operation would be less than that of a fuel-run still. Engineers are hopeful, however, that improved methods and materials will make the plan feasible.

The principle of the solar still is a simple one, and is observed on a grand scale in nature. Clouds are droplets of water evaporated from the surface of the sea or from damp ground and then condensed high in the air. In the process of evaporation, solids such as salt are left behind. Many readers will be familiar with the commercial harvesting of salt in shallow ponds, for this is one of the oldest of man's uses of solar energy.

The still we are going to construct uses the same principle, but it is a little more complex than simply letting sea water run into a pond to evaporate. By means of a

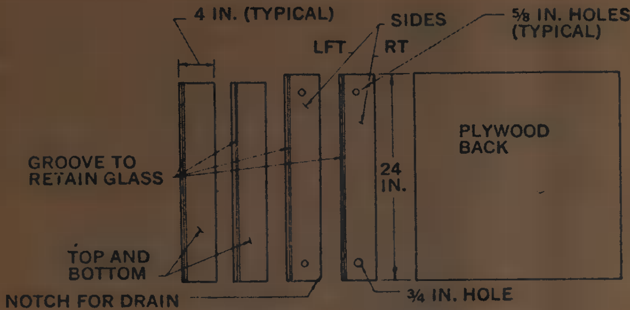
glass-plate collector we increase the temperature in the still to speed evaporation. The design is borrowed from Dr. Telkes, and has been proved by careful testing over a long period of time. Researchers have shown that it is possible to produce almost a quart and a half of water a day for each square foot of the collector's surface. Thus the still should have a maximum output of more than one gallon a day. Of course, this figure represents ideal conditions, but it will be interesting to compare your results with it. The still described here was tested in midwinter, and produced more than one quart in six hours.

Materials

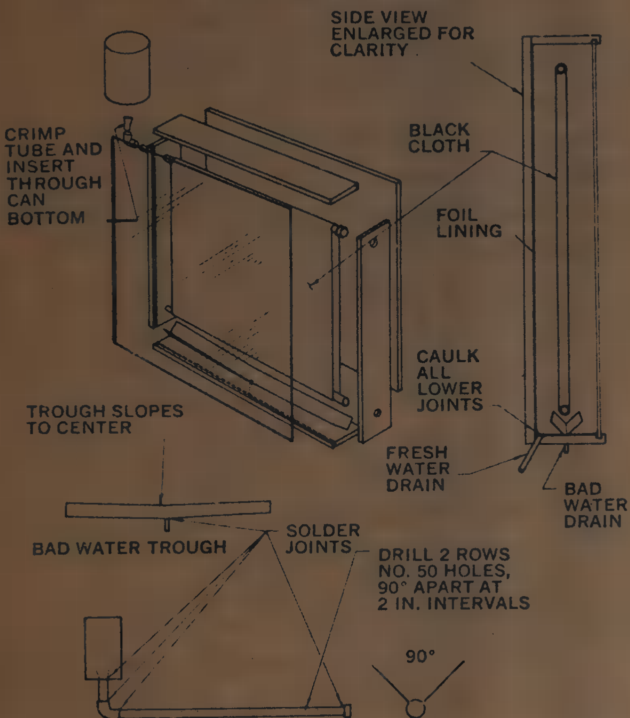
1-by-4-inch redwood board — 8 linear feet
1/2-inch plywood — one piece, 24 by 24 inches
Single-weight window glass — one piece, cut to measure
1/2-inch O.D. copper tubing — 4½ feet
1/2-inch, 90-degree copper elbow — one
1/2-inch copper pipe cap — one
Galvanized iron — one piece 3 by 24 inches
1/4-inch I.D. copper tube — six inches
Large tin can — one
1/4-by-1½-inch wood screws — approximately 30
Black terry cloth — approximately two yards (one large bath towel)

To begin construction, first assemble all the needed materials (except the glass). Redwood is preferred where possible because it resists rotting, while other woods will deteriorate with constant exposure to water.

At the lumberyard where you buy the 8-foot board (1 by 4 inches) have a groove cut 1/8 inch wide to a depth



WOOD PART PATTERNS



FEEDER ASSEMBLY

SOLAR STILL

of 3/8 inch. Locate the cut 1/2 inch from one edge. This is the slot for the glass window. Next cut the 1-by-4 redwood sidepieces to the proper length as shown in the drawing.

Drill two holes at each corner of the sidepieces and assemble with wood screws. The 1/2-inch plywood back may now be put in place and holes drilled for screws. Notice that no screws are put in at the corners, to prevent interference with those holding the sides together.

Mark the locations for the large holes that will receive the 1/2-inch tubing. Drill a 1/8-inch hole as a guide, and then drill three 5/8-inch holes and one 3/4-inch hole, as shown. Be sure the large hole is the proper size for the cap, which we'll solder to the end of the top tube.

The two drain holes can now be drilled, both of them 1/4 inch in diameter. One of these is located in the center of the bottom 1-by-4; the other is in the side 1-by-4, positioned at the vee formed by the bottom and plywood back. Study the drawing to be sure of locating this hole properly. The side drain can now be inserted.

Now is a good time to calk the joints at the bottom and sides and apply several coats of sealer to the inside of the collector box. This is done to make it watertight, and so that the distilled water will run out the drain tube and not seep through the bottom of the box. Allow to dry thoroughly and check for leaks.

We know that any surface receiving heat will reradiate part of that heat. To prevent as much heat loss as possible, and also to present a smooth surface for condensation of water vapor, we line the inside of the box with aluminum foil. Running the foil in one piece across the

plywood back and the bottom 1-by-4 will make an additional waterproof layer to help proper drainage. Notice that the foil extends into the bottom glass slot also.

Foil 24 inches wide will do the job in one piece. If it is necessary to use narrower foil, apply the section toward the drain tube first and lap the other section over it. Use glue, rubber cement, or airplane dope to apply the foil. Start at the top, carefully unrolling the foil for a smooth job. Let the edge of the foil extend a quarter inch past the edge of the glass slot. This excess will be forced into the slot later when the glass is slid into place. Next line the inside surface of the other three 1-by-4's to complete the job.

Since some salty or otherwise undesirable water may not be evaporated before it reaches the bottom of the black towel wick, we provide a vee-shaped trough to catch this waste and prevent it from mixing with the distilled water at the bottom of the still. Made from galvanized iron, this 24-inch trough is a 90-degree angle with legs 1½ inches wide. This can best be bent at the sheet metal shop.

Drill a hole in the very center of the angle, as shown, to receive the center 1/4-inch copper drain tube. Put the short length of tubing in place and solder securely. To keep the waste water from spilling out the ends of the trough, it is curved slightly by "crimping" the edges in several places.

Once the drain trough is completed it may be put in place by inserting the copper tube in the hole drilled for it. This should be a snug fit. Carefully punch through the aluminum foil first with a pencil, then press the trough

down until it just touches the foil at the center.

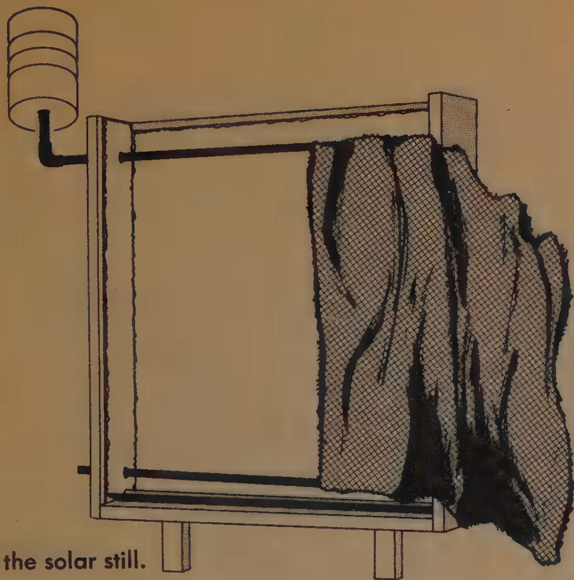
We are now ready to start on the "wick" for the still. The 1/2-inch tubing used at the top and bottom to support the toweling is cut to size with a tubing cutter or fine hacksaw. Or ask your hardware dealer to do this for you, being sure to give him accurate dimensions.

In addition to holding the toweling in place, the top tube is the distributor for the water supply. To accomplish this we drill two rows of No. 50 holes, at right angles to each other. The holes *do not* go through both walls of the tubing and are spaced approximately 2 inches apart.

Our still uses a quart can as a reservoir. Cut the top from a large juice can and remove the paper. Next, cut a 4-inch length of 1/2-inch copper tubing and flatten one end in a vise or with a hammer. This tube will serve to meter the water into the long tube so that too much isn't fed to the toweling.

With a chisel, carefully cut a slit in the center of the can bottom. Allow the metal to bend inward slightly, and check the size of the slit until the flattened tube fits snugly with about 1/2 inch of it extending inside the can. Solder the tube in place, making sure it remains lined up.

Now slide the cap onto the far end of the drilled top tube and solder it in place. Push the tube through the holes in the box, being careful of the aluminum foil lining. Prop up the box so that it is tilted back about 45 degrees from the vertical and rotate the tube so that the two rows of holes are properly positioned to feed water into the toweling when it is looped around the tube. The tilt of our still will vary with the position of the sun, so



Assembly of the solar still.

we are striking a happy medium in locating these holes.

With the tube in the right position, force the end cap into the 3/4-inch hole. This should be a snug fit and hold the tube in the proper place. Now solder the 1/2-inch elbow to the open end of the tube so that it points straight up. The free end of the tube soldered to the can is inserted in the elbow and soldered in place. Some water in the bottom of the can will prevent the joint at the can from melting while you work on the elbow.

Now attach a hinged 1-by-4 prop to the back of the box, using small wood screws as required. This supports the still and also gives us a means of adjusting the tilt to best face the sun. At this time also nail on the two legs, making sure to leave the proper one about 1/4-inch long so that water will run *toward* the fresh water drain.

Smooth the ends of the bottom tube that will support the toweling and insert it in place. Now we are ready to

sew the toweling together. The still in our plans uses a towel 24 inches wide, with the ends lapped and sewed in two places to make a loop. In measuring for this, make the loop slightly smaller than the distance between the tubes, because the towel will stretch somewhat when wet. Too much sag would cause it to touch the back of the box and thus contaminate the distilled water.

With the towel sewed together and dampened, slip the 1/2-inch tubes halfway out and start the towel loop onto the tubes inside the box. The bottom tube is slid back into place first, then the top tube is carefully raised into position and forced back into the 3/4-inch hole. Adjust the towel so that it covers the entire length of the tubes and is smooth. Do not let it touch the sides of the box.

At this point, remove the top 1-by-4 piece so that the dimensions for the glass can be taken. Slide a heavy piece of cardboard into the grooves. Trim to fit. Have your glass supplier cut the glass to measure. The grade of window glass known as "water-white" allows more of the sun's rays to pass than ordinary glass does and is therefore more efficient for our purpose. However, if it is not available, standard single-strength glass will do.

Slide the glass into position. Make sure it is as clean as it can be, particularly on the inner surface, which will not be easy to reach when the still is assembled. Detergents may interfere with proper forming of droplets on the glass, so use plain water for cleaning.

Handle the glass very carefully to avoid cutting yourself on the sharp edges. With the still at a 45-degree angle, start the glass into the slots and ease it downward. When it contacts the aluminum foil at the bottom groove

SOLAR ENERGY SOCIETY

Solar still (designed by Batelle Memorial Institute) at Daytona Beach, Florida.

it should force the foil neatly into place. Replace the top piece, tighten the screws, and the still is ready for operation.

Distillation is easy with our solar plant. First, orient the still so that the sun's rays strike it as close to a right angle as possible. Mount the still on a level surface so that the uneven legs will give it the proper slant for draining. If the reservoir can is not vertical, carefully twist it until it is. The towel should be snug enough to hold it,

and the force fit of the end cap in the 3/4-inch hole helps in this respect.

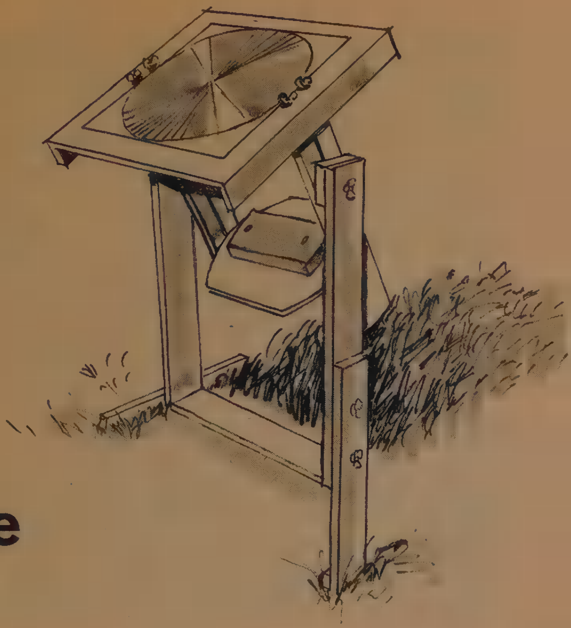
Now fill the reservoir, and to make sure that the still really works, add some salt to the water! After a few minutes the towel will begin to receive water from the distribution tube. If it doesn't, or if the flow is too slow, very carefully open up the flattened tube in the bottom of the can with the point of an ice pick. Be cautious about this, however, as we don't want the water to flow into the towel faster than it can be evaporated.

Heat from the sun is trapped in the box, and the black towel absorbs this. Water is therefore evaporated from the towel much faster than it would be normally. The vapor, free of all solids, recondenses on the smooth surface of the glass and the foil on the back and sides. You'll see this a few minutes after you put in the water; first the glass steams up, then droplets form and run down to the bottom.

Don't expect the water to gush from the still like a Niagara, but put a can or bottle under the drain to catch the distilled water. On a sunny day the still will begin producing soon after you set it in operation and will drip water steadily into the container. To guard against evaporation of this distilled water, some experimenters run a tube from the drain to a corked bottle.

At first you will probably reposition the still every half hour or so for greatest efficiency. When the novelty wears off and you want to leave the still for steady operation, decide on a compromise tilt—your latitude plus 10 degrees or so, and aim the collector south (unless you live below the Equator, of course).

4
A Solar Furnace



MOST of us learned at an early age that the magnifying glass would do more than simply enlarge the type in a book. A converging lens magnifies heat as well; that is, it concentrates the sun's rays into a small space. By changing a relatively large amount of warmth into a small amount of heat, we burn our initials in wood, start a campfire, or, as with our reflector stove, cook a meal. It is this same principle of concentration that makes possible the huge solar furnaces in operation today. A lens, or mirror, whichever the case may be, intercepts a certain amount of sunlight, focuses all of its heat energy onto a tiny spot, and thus produces temperatures as high as 6,500 degrees F.

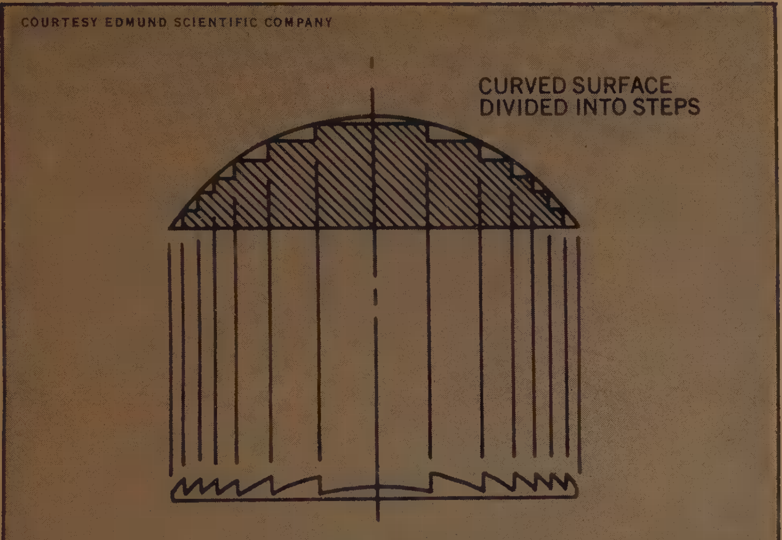
Centuries ago, scientists were able to melt metals at temperatures in the neighborhood of 2,000 degrees F. even with the comparatively crude furnaces they were able to construct. Modern technology has made it possible for the solar furnace to create the hottest temperatures available to man for any appreciable length of time. Of course, such methods as the "shock tube" and plasma jet techniques do produce higher temperatures, but only at great cost and for limited periods of time.

In France a 35-foot furnace has operated for many years, and has performed satisfactorily in melting metals for industrial use. The largest furnace in the United States today is that of the Army Quartermaster Corps, which is about the same size.

Obviously these furnaces cost fortunes to erect, but anyone can build himself (or herself) a workable solar furnace for about ten dollars and in a few hours. Far from being a toy, the result is a practical tool that will melt metals with fairly low melting points, do soldering jobs, and even heat a kiln for firing ceramic jewelry.

Back in 1770, the French experimenter, Lavoisier, had convex lenses made especially for him by the same St. Gobain glass works that is still in operation today. These curved pieces of glass were joined together at their rims and filled with wine to make them equivalent to solid lenses. Light passing through them was refracted or bent in toward a common focal point to heat whatever samples the scientist placed there.

A convex glass lens of the size needed for our furnace would cost far too much for the average budget, but for-



Principle of the Fresnel lens.

tunately there is a substitute. There is a clever way of making a thin, grooved piece of plastic take the place of the lens. Called a Fresnel lens, this type will serve our purpose well.

As the sketch on this page shows, the curved surface of the lens is cut into small segments of equal height, and in effect is flattened out into the thin form shown. While cutting such a lens from glass is costly, plastic Fresnel lenses are made for a reasonable price from a master form. The one used in our project cost six dollars, and therefore gives about 300 degrees of heat for each dollar spent!

We could, of course, immediately begin to use our lens for melting, soldering, and so forth, much as we would use a smaller burning lens. But holding the lens in one's

hands and trying to keep it accurately focused on the specimen would soon tire the most ardent experimenter. A necessary part of our furnace, then, is the mounting.

To understand why we use the type shown it will be a good idea to consider just how the sun moves across the sky during the day. We are designing a furnace to move with the sun. Because the Earth rotates on its north-south axis, the apparent movement of the sun is at right angles to this, rising in the east and setting in the west. (This is a simplification, and readers familiar with astronomy know the actual movements are somewhat more complicated.) Further, the sun seems to move approximately along a parallel of latitude in its daily journey, which is called its declination. We are all acquainted too with the movement of the sun south in wintertime, but now we are considering just one day's motion of that body.

For greatest usefulness our mounting should be one that will easily "track" or follow the sun, and for this purpose the equatorial mounting is ideally suited. This is the type used in telescopes, so designed that a motor turning it at the right speed will keep a star or other body in the field of vision continually. Of course, in our simple solar furnace we will not include such an automatic system, but the large furnaces operate in this way or with a photoelectric device that keeps the sun's image properly positioned.

Set up correctly, our furnace mounting is so designed that we have only to tip the swinging part to follow the sun. In practice we will find that since the sun moves only about one degree in four minutes we can often accom-

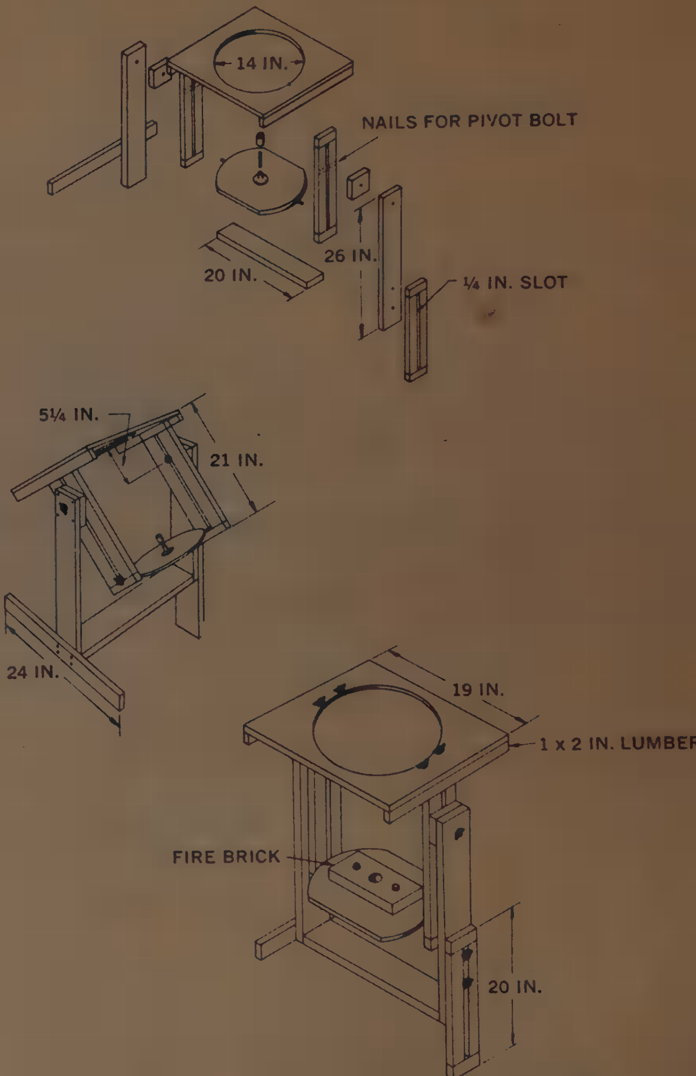
plish our soldering, melting, or other operation without moving the lens. However, at times the convenience of the equatorial mount is desired.

Now that we have briefly discussed the theory of operation of our furnace, let's get busy and build it. As in previous projects, see that everything is on hand before you begin. That way the job won't take long and you will soon have your furnace in operation.

Materials

1-by-4-inch lumber – approximately 16 feet
3/4-inch plywood – 19 by 19 inches
1-inch wood screws – 16
1/4-by-4-inch studs and wing nuts – six
1/4-by-2-inch bolts and wing nuts – four
14-inch (diameter) Fresnel lens – one
1/4-inch chuck – one

A Fresnel lens of the type we mentioned may be obtained from the Edmund Scientific Corporation, Barrington, New Jersey. This is made of thin plastic. Edmund also furnishes information on building other types of solar furnaces. Check with your photographic supply dealer and surplus stores for other suitable Fresnel lenses. A thicker, rigid type of rectangular shape is sometimes available and is more durable than the thin plastic. The firebrick kiln may be of any type that will stand the great heat developed at the focal point.



SOLAR FURNACE

Use a good grade of wood for the various parts of the furnace. Cheap lumber is a poor economy, because warping will result in a second-rate finished product. In addition to the materials listed, we will need a drill, saw, and screw driver.

With a piece of string, mark a circle on the 19-inch square of plywood, as shown in the drawing. Make sure the circle is centered accurately. Drill a starting hole just inside the line, and use a keyhole saw to cut out the center. Save this piece of scrap for the work table of the furnace on which we will later mount the kiln and adjustable chuck.

Next cut the 1-by-2 strips that form the swinging frame, making sure all ends are square. Assemble with wood screws to form the slotted track that permits adjustment of the work table. Drill holes in two places in each assembly for the finishing nails that form bearings for the pivot bolts. Double check to see that the slots are wide enough for the 1/4-inch studs to slide smoothly up and down, and set these parts aside.

Now drill four holes in the plywood lens frame for the mounting studs as shown in the drawing. Carefully place the slotted parts in position and mark matching holes in their top ends. Drill for studs, and screw the studs in place. Leave enough protruding above the plywood for a washer and wing nut, plus several extra threads for mounting the lens in case you use the "glass sandwich" method to be described.

Next cut the three pieces that form the yoke for holding the swinging frame. Assemble the "U," and nail the

Furnace with kiln mounted on it.

square spacer blocks in place on the top, inside surface of the side pieces. Drill 1/4-inch holes for the pivot bolts through the sidepieces and spacer blocks. Attach the horizontal support with four wood screws so that the yoke will stand upright, and drill two 1/4-inch holes in the sidepiece opposite the horizontal support. These holes are for the bolts that hold the sliding declination adjustment piece, which may now be slotted as shown on the drawing.

If you have a drill press and a reamer-type drill bit that cuts on the side, this slotting operation will be simple. If not, it may be done by drilling separate holes as close together as possible, and then cleaning them out with a keyhole saw or a chisel. Go ahead and fit the sliding piece to the yoke with bolts, washers, and wing nuts.

Now we can come back to the circular piece left from the center of the lens frame. Trim the sides straight to eliminate the starting hole, and then drill two holes on opposite sides to receive studs. Insert the studs. The worktable can now be attached to the side supports by means of washers and wing nuts.

Place the lens frame in position and slide the pivot bolts between the finishing nails to complete assembly of the mount. All that remains to be done is to install the lens. There are two ways of doing this.

It is possible to simply glue the lens in place with an adhesive such as Goodyear Pliobond. An alternate method is to place the lens between two thicknesses of window glass and attach it to the lens frame by means of the washers and wing nuts.

If you want to use the gluing method, follow these instructions carefully. Remove the frame from the mount and apply thin coats of glue to the area to be covered by the lens. Several coats may be required to fill the pores of the wood. Add one more coat and let dry for a minute or so. This final coat should be brushed out carefully so that it is uniform and not too thick; otherwise the plastic lens will not adhere properly or pull tight the way it should for best results.

Very gently place the lens in position on the frame, keeping it smooth, but without trying to stretch it. Be sure that the grooved side of the lens is up, or the furnace will not operate! With the lens in place, set it aside to dry for a day.

Because the Fresnel lens is plastic and can easily be damaged, a good way to add to its life is to sandwich it between two sheets of glass of the proper size. The photograph shows this method in use. When not in use the lens can be removed and stored for safekeeping. Another advantage is that the lens is held more nearly in a plane than it is in the gluing method. Unfortunately the glass does cut down the amount of heat transmitted through the lens, so the choice is one between high temperature and durability. If it is available, use "water-white" glass as previously described.

If you plan to use the furnace only for soldering, jewelry work, and so on, you may want just the firebrick kiln. With a masonry drill, drill two holes in the brick and matching holes in the worktable. If you don't have such a drill, the brick can be wired in place. For jewelry work

SOLAR ENERGY SOCIETY

A Japanese solar furnace used in industrial research and capable of generating temperatures of several thousands of degrees Fahrenheit.

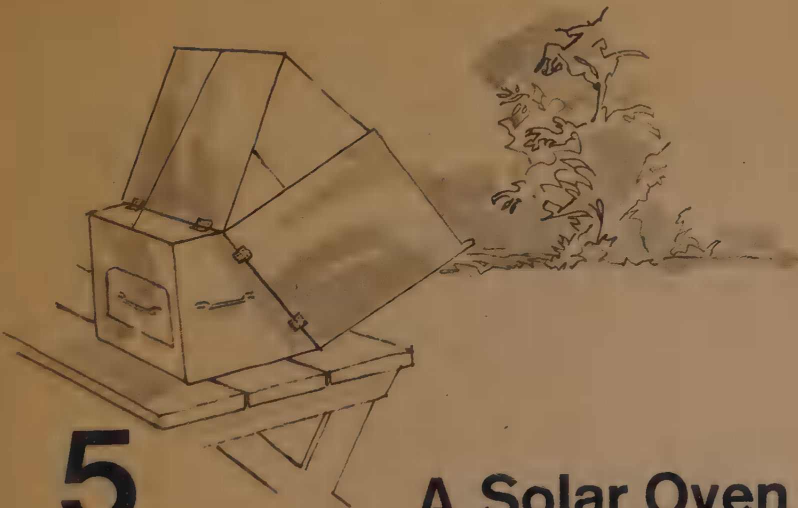
it is handy to drill a shallow hole in the brick to hold small pieces.

For experimental work it is also handy to have the adjustable chuck setup shown in the photograph. Metal

samples are then easily placed at the focal point. A chuck from a discarded hand drill will serve the purpose, along with a length of rod threaded to fit the chuck. A mounting flange is screwed to the worktable to receive the rod, which may be adjusted to position the chuck as required. Of course the firebrick will have to be removed for this operation.

Using the furnace is quite simple. Place the mount with the horizontal support toward the south (unless you live in the Southern Hemisphere), loosen the pivot wingnuts and tip the lens frame toward the sun. Wear dark glasses whenever you are using the furnace because the bright spot at the focal point can harm unprotected eyes. Now adjust the sliding declination bar until the image from the lens is centered on the worktable. It is a good idea to have the firebrick in place when setting up the first time so that you won't burn holes in the worktable.

Tighten the wing nuts to hold the mount in place, and loosen those holding the worktable. Slide it back and forth until the bright spot in the firebrick kiln is at its smallest. The furnace is now focused, and the temperature should be close to 2,000 degrees F. with bright sun. You will understand now why we have made the table adjustable for purposely shifting focus for less heat. Experience will be the best teacher here. Meantime, be careful of hands and eyes while you use the furnace.



5 A Solar Oven

THE "greenhouse" effect is well known to those who grow plants in such structures and also to those of us who have left the windows of a car rolled up on a warm, sunshiny day. The rays of the sun go through the glass well enough, but the reflections of longer wavelength are unable to bounce back out of the car. The result is aptly described as resembling an oven. And that is just what we are going to build in this chapter—a solar oven that will do a real job of cooking on a clear day, even in winter.

One aim of solar scientists is to provide a means of cooking for those countries in which fuel is scarce or expensive. Dr. Maria Telkes, mentioned in the chapter on solar stills, designed such an oven, which she feels might be mass-produced at a reasonable price. Our design is copied from the Telkes oven, which has been demonstrated in foreign lands.

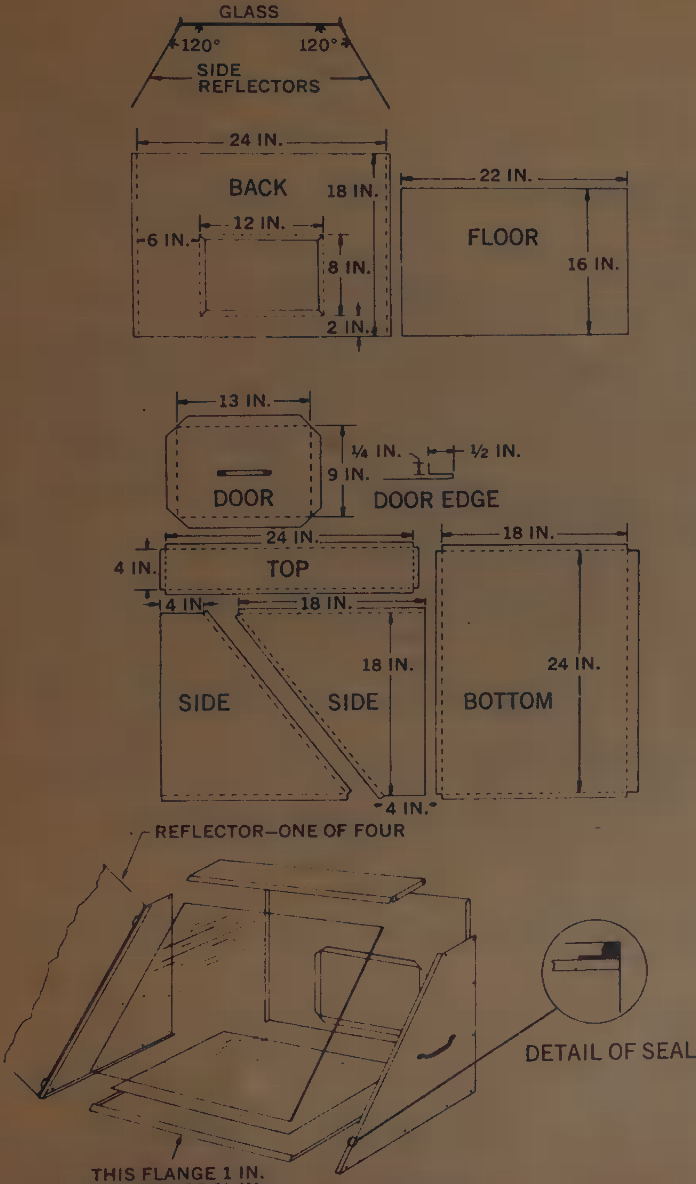
Basically the solar oven consists of a box for the food and a glass cover to admit and trap heat inside the box. The box shown is made from galvanized iron but could as well have been aluminum for lighter weight. The reflector panels are of aluminum.

Besides the sheet metal parts, we need a piece of double-strength window glass, a sealing strip for the glass, and three handles. We will insulate the box with spun glass material 2 inches thick for greater heat retention.

Materials

28-gauge galvanized iron – 16 square feet
No. 6, 3/8-inch sheet metal screws – approximately 24
2-inch fiber glass insulation – 12 square feet
Double-strength window glass – 22 by 24 inches
Drawer pulls – three
Flat black paint – one spray can
2-inch roofing nails – six
Sealer strip – eight feet
Aluminum sheet .025 by 22 by 24 inches – four pieces

Again, it will be a good idea to have all materials on hand before beginning the project. One exception could be the sheet metal for the box, in case you decide to let your local sheet metal shop do the cutting and bending for you. This is a good idea unless you are familiar with metalwork, and will result in a more professional job at little additional cost.


GLASS
120°
120°
SIDE
REFLECTORS
24 IN.
BACK
18 IN.
12 IN.
6 IN.
8 IN.
2 IN.
22 IN.
FLOOR
16 IN.
13 IN.
¼ IN.
½ IN.
9 IN.
DOOR
DOOR EDGE
24 IN.
TOP
4 IN.
18 IN.
4 IN.
18 IN.
18 IN.
SIDE
SIDE
24 IN.
BOTTOM
4 IN.
REFLECTOR—ONE OF FOUR
DETAIL OF SEAL
THIS FLANGE 1 IN.
ALL OTHERS ¾ IN.

SOLAR OVEN

If you want to do all the work yourself, and feel that you can handle the job, this is the way to begin. The bottom of the oven is a rectangle of metal, with the corners notched out to allow bending up the flanges all around the sides. These flanges are 3/4 inch, and are bent up 90 degrees, except for the front edge, which is a closed 45-degree angle, 1 inch long, as shown in the drawing.

The right and left side panels may be cut from one rectangle of metal to save material. Lay them out carefully to prevent waste. Again, flanges are bent 3/4 inch wide at the front and top. The back and bottom edges are left flat. Be sure to make the bends opposite on each part so that you will have a right-hand panel and a left-hand panel, and not two of a kind!

The oven back has 3/4-inch flanges on each side and an opening cut in it for the door. Notch the corners of the opening 45 degrees and bend the 1/2-inch stiffener flanges in the same direction as the side flanges. This will strengthen the door opening and also give the back a finished appearance.

Now make the top of the box. This is a channel with one flange at 90 degrees to fit the back and the other flange open to 45 degrees to match the slope of the glass. Next come two retaining angles 18 inches long, with 3/4-by-1-inch legs. The box is now complete except for the door.

The door is the only difficult part to make; care must be taken to bend it correctly. The double, or "hemmed," edge strengthens the door, and the flange left standing will fit into the opening in the back of the box. A snug

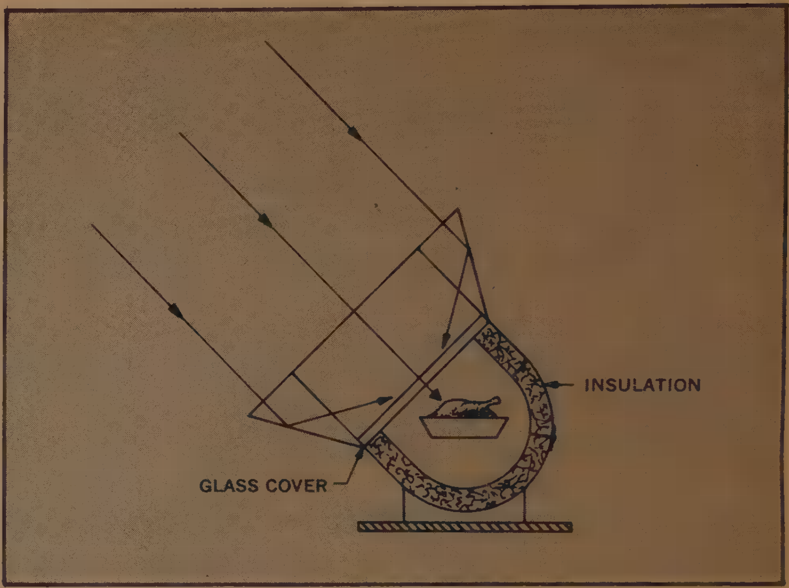
fit here will make for a neat, effective door that will seal properly and help keep the heat inside where we want it.

A false bottom is needed to prevent collapsing of the insulation under the weight of the food. It is a rectangle of metal sized as shown in the drawing. Make sure it is not so large that it contacts the front, sides, or back of the box. This would cause heat loss by conduction to those parts.

It might be well to mention here that an alternate method of construction can be used, employing a little ingenuity and the "do it yourself" aluminum sheets and angles available at the hardware store. This method uses flat sheets, with angles attached to them instead of flanges bent from the sheets themselves. Of course, the 45-degree angles would have to be eliminated, and a slightly different sealing technique used for the glass, but some builders may prefer doing it this way.

Now, with the metal parts formed either in the sheet metal shop or at your own workbench, we are ready to begin assembly of the oven. The simplest way to put the oven together is with sheet metal screws. Use 3/8 inch, No. 6 screws for this purpose. They are available at the sheet metal shop, or your hardware store. If you are using aluminum, substitute hardened aluminum screws, since different metals coming in contact with each other may cause a corrosive action.

Mark pencil guidelines 3/8 inch from the bottom edge of the side panels, spaced as shown on the drawing. Center-punch the holes and drill with a No. 40 drill. A hand drill is fine; an electric drill is even better for this



How the solar oven traps heat.

purpose. Now, with the bottom of the oven on a flat surface, hold the side panel against it and in its proper place. Drill through the holes in the side panel and on into the flange of the bottom. It is a good idea to put in a screw as each hole is drilled to insure perfect alignment and prevent shifting of the parts. Notice that the bottom flange overlaps the side but no holes are drilled at this point.

With both side panels attached to the bottom, the back of the box may now be put in place and holes drilled. Continue to insert screws as holes are drilled, carefully keeping the parts lined up as you progress. The oven is taking shape by now, and needs only the top to be added.

Before we do this, however, we will install the glass in the front of the box. Needless to say, care must be taken during this operation so that the glass will not be broken. Don't cut your fingers on the edges.

Clean the glass carefully with water. Then glue on the sealing strip around the edge with a good cement (Goodyear Pliobond works well), following the directions to insure a strong joint. If you were able to find a sealer that fits over the edge of the glass the job will be easy. If you are using the bulb type, additional care will result in a neat assembly.

When the sealing strip is attached and properly "set" the glass may be put in place in the oven. Slide it down through the top, which we have left open for this purpose. For this operation lay the oven on its front face, being sure to have a perfectly flat surface to work on.

We will now install the 18-inch angles that hold the glass in place. Carefully drill holes in the sides of the box as shown on the drawing, locating them so that they will match the angles when they are put in position. Slip the angles through the opening in the top and set them on the glass with the 1-inch leg flat against the side of the box.

Working from the top, or reaching through the opening in the back of the box, press one angle very lightly against the glass. Do not force the glass so that it flattens the sealing strip, because this strip acts as a cushion to prevent breakage of the glass, in addition to its sealing function. While holding the angle, mark through the holes in the side to indicate the proper location for the

The solar oven is large enough to cook a complete meal at one time. When not in use, reflectors fold to protect glass.

holes in the angle. Remove the angle, drill holes in it, then replace and insert a sheet metal screw. Repeat this process on the other side.

With the glass installed, the top may be put on and holes drilled through it and into the back and sides. Notice that the top fits over the back and side panels.

The oven is now complete except for the carrying handles on each side and a similar handle on the door. These are attached with screws.

Fit the door into the opening and mark the holes for the turn-buttons that hold the door tight. Drill 3/16-inch holes in the back panel, and install the turn-buttons with nuts, bolts, and washers. The washers hold the buttons away from the metal so they will clear the hemmed edge of the door.

The spun glass insulation is now cut to proper shape with a sharp knife or linoleum cutter. Use a straightedge for accurate trimming. Plan carefully so as not to waste material. The bottom piece can be beveled 45 degrees at the front if care is taken. Paint the inside surfaces of the insulation with flat black enamel, using a pressure can for convenience.

After the paint is dry, the insulation is glued into the box with Pliobond or its equivalent. To do this, remove the back of the box and set it aside. Positioning the oven with the glass down, cement the top insulation in place first and allow to dry. Tip the box right side up and cement the bottom insulation in place. Press five 2-inch roofing nails point-down into the insulation and lay the false bottom over them. This bottom piece is painted flat black too. The side insulation can now be cemented into place and the box is complete except for the back.

Cement insulation to the back panel, cut the small rectangle from the opening and place it on the inside of the door. The back may now be carefully replaced and the screws inserted. Put in an oven thermometer, fasten

the door in place, and we are ready for the reflector panels, which are hinged to the box as shown in the drawing.

In tests the box itself will reach an inner temperature of only about 250 degrees. This is because heat loss to the surrounding air prevents the temperature inside from climbing higher. If we could increase the amount of heat going into the box, the oven would get hotter. For this reason we add the aluminum reflector plates shown in the photograph. Use Alclad if it is available.

Rivet two hinges to each reflector. Be sure to have two reflectors hinged on the ends and two hinged on the sides. If the Alclad sheets have red lettering on one side, use the opposite side for the reflecting surface. Attach the hinges to the box with sheet metal screws, installing the bottom reflector, then the sides, and finally the top. Besides their primary purpose, the reflectors also protect the glass.

An angle of 30 degrees to the received rays of the sun will reflect them into the box; so we open the side panels to this angle. We face the oven directly toward the sun, and thus this angle will always suffice for the side reflectors. The 45-degree tilt of the glass is a compromise angle that gives all-around performance. However, a little thought will tell us that for maximum performance the angle of the top and bottom reflectors will vary with the position of the sun in the sky.

The discussion sounds complicated, but in practice adjusting the oven is very simple. Set it out in the sun, preferably on a wooden table, and face it toward the sun. Open all the reflectors. Now swing the top reflector up

The solar oven turns out a pie.

and down while watching the inside of the oven. You will be able to tell when you have it at the proper angle by the reflection of the sun's rays on the dull black insulation. Bend the end of a piece of galvanized wire to act as a stop, insert this wire in a hole in the top reflector, and wrap the free end around the loosened screw as shown in the photograph.

Swing the side reflectors into position, checking the angle they make with the glass by means of a cardboard template. Using two wires, attach them to the top reflector. Now swing the bottom reflector up, watching the inside of the oven again. When it is properly positioned, fix two wires in place from the bottom reflector to the side reflectors, and the oven is ready.

The test oven shown in the illustrations reached a temperature of 350 degrees in 15 minutes. This was in Arizona in mid-January, with the air temperature in the low 60's. The first time it was used it baked a loaf of bread in just over an hour, and then cooked a three-pound roast in three and a half hours! A whole meal can be cooked in the solar oven. The menu is limited only by your imagination.

6 A Solar Water Heater

MANY thousands of solar hot-water heaters are in use today. Perhaps you have seen one—a glass-plate collector containing a copper coil and a storage tank for holding the sun-heated water. This type of heater was in use at least as long ago as the 1930's in California and Florida. Even the crude, makeshift designs of those days did a fair job of providing hot water for domestic use. Of course, standby heat in the form of gas or electricity had to be provided for cloudy days and night use.

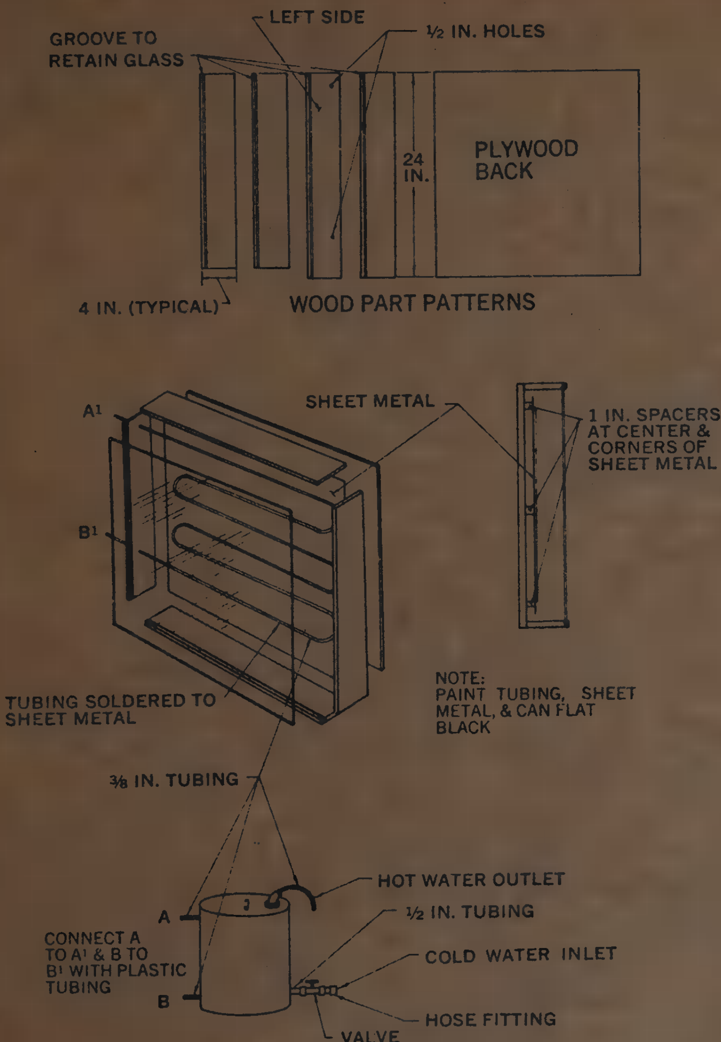
To risk a pun, the sun really shines when it comes to heating—either air or water. Conversion of solar rays into heat can be done with an efficiency as high as 50 per cent, as compared with the 11 per cent efficiency of the solar battery. As we have said, there are thousands of solar heaters now in use, and we may expect widespread use of the sun as space heater and water heater in the future.

The heater described in this chapter is not intended for domestic use, but primarily to demonstrate the principle of heat transfer and its use in this application. However, the five-gallon tank would make a good supply for camping trips or for a cabin that has no provision for hot water. If desired, an enlarged version of the heater could be installed on a roof, connected to a water supply, and used as a permanent hot-water source.

We'll begin our heater with the collector box itself, which is very similar in form to that used in the solar still. Make the sides of the box from 1-by-4 material as in the solar still. Redwood is not absolutely necessary this time since there will be no dripping or condensing of water which might rot the wood.

Materials

1-by-4-inch redwood board – eight linear feet
1/2-inch plywood – one piece 24 by 24 inches
Single-weight window glass – one piece, cut to measure
3/8-inch O.D. copper tubing – approximately 16 feet
Sheet copper – 22 by 22 inches
1/2-inch copper tubing – three inches
1/2-inch valve – one
3/4 inch female hose fitting – one
5-gallon can – one
3/8-inch I.D. plastic tubing – 10 feet
1/4-by-1½-inch wood screws – approximately 30
Flat black paint – one pint



SOLAR WATER HEATER

At the lumberyard where you buy the 8-foot board (1 by 4 inches), have a groove cut 1/8-inch wide to a depth of 3/8 inch. Locate the cut 1/2 inch from one edge. This is the slot for the glass window.

The next step is to cut the pieces to the proper length, being sure to keep the ends square both ways. As in our other project, the glass should fit snugly.

Next cut out a square of plywood 24 inches on a side and place the 1-by-4 pieces on it to make sure they fit. Assemble the sidepieces to the back with wood screws, using the same procedure described in the solar still chapter.

Take the box apart at this point and clean chips and shavings from the holes. Drill two 1/2-inch holes in one of the sidepieces as shown on the drawing. These holes accommodate the copper tube coil which will carry water from the tank to the collector and back again. Now cement aluminum foil to the inside surface of the plywood base. As in the still, this reflective material serves to bounce back radiated heat so that it will not be wasted.

Next, five small spacer blocks (1-inch cubes) are nailed into place as shown on the drawing. These blocks are the same thickness as the distance from the edge of the 1-by-4 piece to the 1/2-inch holes, and thus serve to hold the coil the proper distance from the plywood base. Small finishing nails will be fine for attaching the spacers, but it is best to drill a hole through each block first to prevent splitting of the wood.

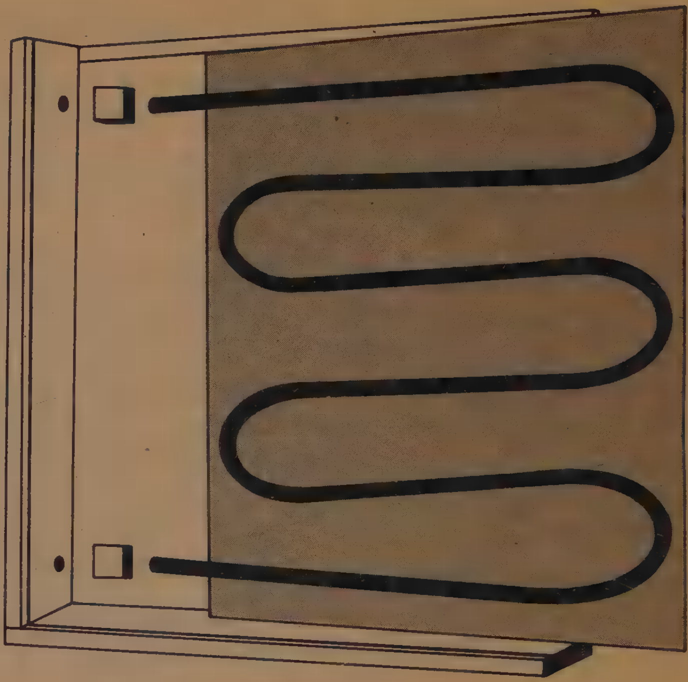
With the box itself completed, we can begin work on the copper coil and the collector plate. These are impor-

tant parts of the heater, since they transfer the intercepted heat from the sun to the water inside the tubing of the coil. Copper is used because it is a very good conductor and will quickly carry heat to the water. Copper is quite expensive, however, and you may want to substitute galvanized iron for the plate to cut the cost somewhat.

If you use a copper sheet, have it cut to exact size. It is sold by weight, and there is no need to pay for scrap. Notice that the size specified allows 1/4-inch clearance all around the inside of the box. Before working with the copper sheet, trim a small piece from each corner at a 45-degree angle to prevent the possibility of being scratched or cut by the sharp edges.

We will bend the heating coil from 3/8-inch copper tube, the flexible kind that comes in a roll. The length called for in the list of materials allows for trimming. First of all, straighten out the tubing, making it as flat and true as you can. It is quite soft, and a little time spent should result in a smooth job. Now lay the tube across the flat sheet of copper, with the proper length extending beyond the edge. Mark the start of the first bend in the tubing with a pencil and then carefully form it around with your fingers into the U-shape shown. Work slowly and evenly so that you will not flatten the tube excessively.

After the first bend is made, replace the tubing on the sheet and make sure the bend is in the proper position and that sufficient tubing extends past the edge of the sheet. Mark the second bend and proceed as before. Continue to form the coil in this manner until the sheet



Partially assembled solar heater.

is covered in a series of S-turns as shown.

Trim the long end of the tubing, check the shape of the coil once more, and then lay it on a flat surface to see that it is level. Spend as much time as required to make the tubing lie perfectly flat, using your fingers and tapping lightly with a rubber or wooden mallet for the finishing touches. The tubing must touch the sheet along its full length for the best heat transfer.

When you are completely satisfied with the job, the copper coil may be soldered to the sheet. Clean the tube

and the sheet with emery cloth so that the solder will stick properly. Lay the sheet on a wooden surface (the inverted collector box itself will do nicely) and place the coil in position. Remember that the ends of the tubing must fit through the holes drilled in the 1-by-4. Now lay a board over the coil, and weight it to keep the tubing in place. We are ready for the soldering operation.

A small torch is handiest for this purpose, but a soldering iron will do the job too. If you aren't equipped for such work, have it done at a sheet metal shop. Solder as shown on the drawing, about 6 inches apart. Be sure to hold the tubing flat to the sheet. Heat will cause the copper to warp slightly, but it will return to its flat position upon cooling.

With the job complete, clean any excess soldering paste from the copper and paint the entire assembly with flat black paint. Apply a second coat of paint for good measure and set aside until completely dry.

The coil assembly may now be slipped into the box, with the ends of tubing carefully inserted into the 1/2-inch holes. Tack the copper sheet to the spacer blocks when you are sure it fits properly and will not have to be removed.

Unscrew the top 1-by-4 piece. Slide a heavy piece of cardboard into the grooves. Trim to fit. Have your glass supplier cut to this measure. Fit the glass into the slots, and replace the top piece. The collector is now complete and we can begin work on the water tank.

A round, five-gallon can with narrow, screw-top spout is used for the storage of heated water. The one here

was a discarded oil can obtained from a local distributor. Other types of containers are suitable and may be substituted if the round type shown is not available. For example, a square, lightweight can will fill the bill. This type is usually on sale at hardware and surplus stores.

Clean the can of any residue of oil or other liquid. This is done for two reasons. First, we don't want the water contaminated and, second, heat from soldering operations might set fire to the liquid. So do the cleaning carefully, and flush with water several times before doing any work on the can.

Two short lengths of 3/8-inch copper tubing are soldered to the can. Location and correct dimensions are shown in the drawing. First drill a 1/4-inch hole in each place a tube is to be installed. Next drive a center punch or other tapered piece of material into the hole. This enlarges the hole and also forces the metal inward. Check frequently during this flaring process to insure a snug fit of tubing. The depression formed in this way will hold more solder and make a stronger joint.

If a painted can is used it will be necessary to scrape the areas where soldering is to be done. When the metal is clean and bright, insert the tubing (which has been cleaned too). Using a torch or soldering iron, let solder flow into the depression and around the tube. This operation is easier if the can is positioned with the tube pointing straight up.

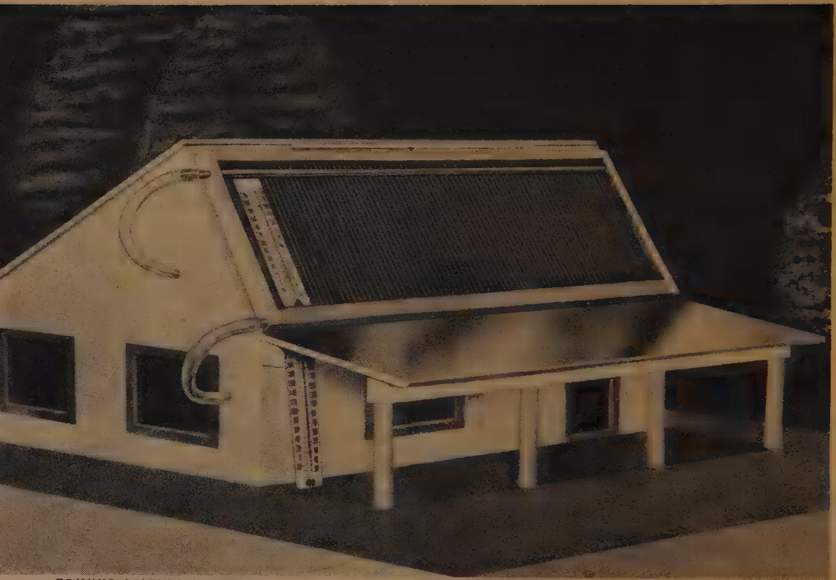
The hot-water outlet is also a length of 3/8-inch tubing, soldered to the screwed-on cap of the can. Use the "flaring" method again so that a strong joint will result. Notice that the tube is bent into a U-shape.

We are now ready to do the plumbing for the cold-water supply line. Instead of 3/8-inch tubing, use 1/2-inch tubing for this connection. Attach a simple shutoff valve to the tube, using compression-type fittings that come with the valve. Your dealer will explain how these fittings are installed. Another short length of 1/2-inch tubing extends from the valve. The free end of this tubing is soldered inside a brass garden-hose fitting of the type used with a plastic hose.

With the soldered joint made, and the compression fittings tightened securely, you can connect the tank to the end of the garden hose and check for leaks. Turn on the water at the faucet, open the valve at the tank, and cork the tubes that will lead to the collector. When the tank is full, water will overflow from the hot-water supply outlet. Mark any leaks, drain the tank,and repair as necessary. The tank is now ready to be attached to the collector coil.

Our heater would be of little use if only the water in the coil itself became hot — this would barely be enough to wash one's hands! Fortunately there is a phenomenon called thermosyphoning which we shall make use of to heat the whole tank of our hot-water system.

If we made a very large collector, the coils would hold ample hot water. Another method would be to install a pump to circulate water between coils and tank. This would cost more money and also make our heater more complicated. Thermosyphoning is the ability of water to circulate of its own accord when heated — given certain conditions. For our purposes, the most important of these



EDMUND SCIENTIFIC CORP.

Working model of "Thomason," solar-heated home built and operated in Washington, D.C.

conditions is that the supply tank be located *above* the coil.

The photograph shows the tank mounted on a wooden stand, with the bottom of the tank about on a level with the top of the collector. As the coil heats water inside it, this water rises and is replaced by cooler water drawn from the bottom of the tank.

Set up the collector facing the sun using a hinged prop, and place the tank on its stand to one side. Install the plastic hose between the two bottom tubes, using hose clamps for a watertight connection. Clamp one end of the second plastic hose to the upper tube of the collector, but leave the other end free.

Fill the tank. When water flows from the open plastic hose, hold it with your finger until water also flows from the top circulation tube of the tank. Then quickly slide the hose onto the tube and clamp it. This prevents air bubbles' being trapped in the lines. When the hot-water outlet overflows, close the tank valve.

Operation of the heater is simple. You will notice that the upper hose quickly gets hot, while the lower one stays relatively cool. Water is circulating now, and eventually all of it will be warmed by the coils. To draw hot water, open the valve at the bottom of the tank. Cold water comes in and forces hot water out the top.

7
Solar Motors

ALL of our projects so far have used the heat of the sun directly for power, and all have been quite easy to understand. In this chapter we will build a sun-charged power supply that makes use of the photovoltaic process, discovered by Becquerel back in 1839. The conversion of light directly into electricity – with no intervening steps – is fascinating. It is also much more difficult to understand.

There was a great lapse of time from the discovery of the principle of photovoltaic conversion to its practical application. At first it seemed no more than a scientific curiosity.

Early photocells used the element selenium, which derives its name from the Greek word for moon. This is an ironic name for a material now used in so-called *sun*-batteries! The selenium cell was first used in exposure

meters, electric-eye devices, and the like. Present-day solar cells of selenium are inexpensive; their only drawback is a relatively low efficiency of conversion — about 1 per cent.

Pioneer experimenters in the field of transistors used the element silicon, then switched to germanium. The unusual properties of silicon were remembered later, however, when efforts were made to develop a more efficient photovoltaic converter. Bell Telephone Laboratories produced solar cells with an efficiency of more than 10 per cent. The company then proved the usefulness of solar cells by powering rural telephone lines with sunlight. Hoffman Electronics Corporation and International Rectifier Corporation are among the leading manufacturers of silicon cells.

A complete explanation of how the solar cell works will be found in books on physics. For the moment we can settle for a simpler view — the knowledge that the sun battery *does* work!

Photons, the bundles of energy in light, penetrate the selenium or silicon and cause the movement of electrons in the material. An unbalance is set up in the cell, so that if a wire is connected between the positive and negative sides, current flows. This flow of current is similar to that in a dry cell, with one important difference. Nothing is added or taken away from the cell; it will produce current indefinitely instead of wearing out as the dry cell will.

What this means may best be understood in terms of our space program. Conventional batteries are bound to

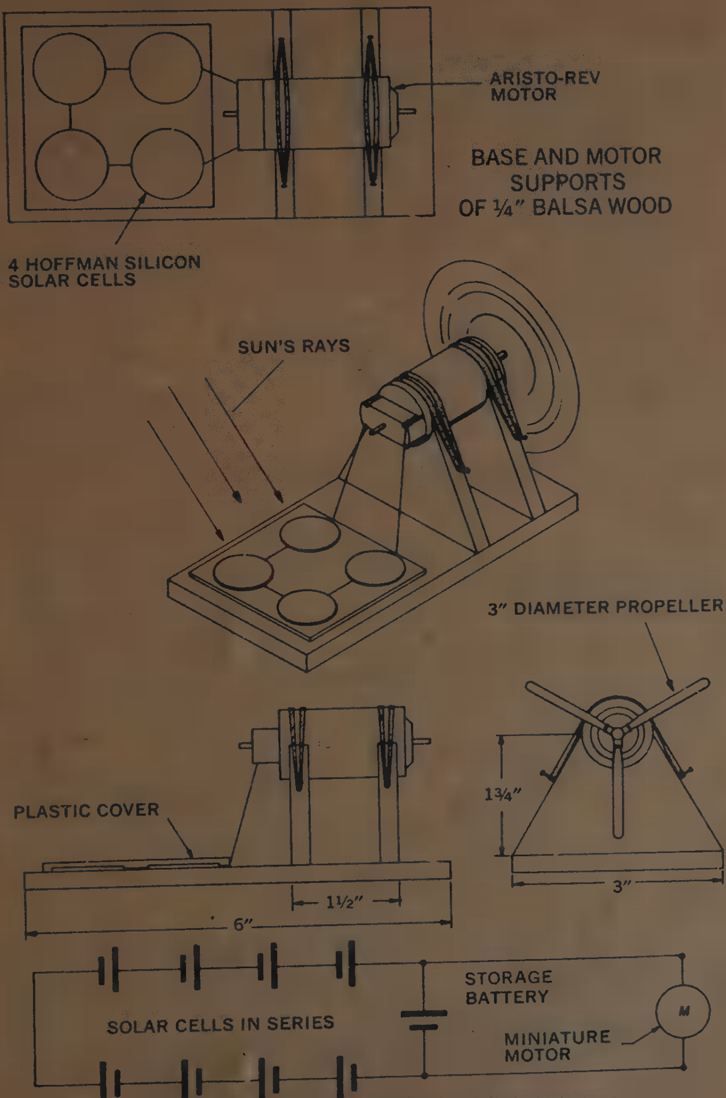
wear out. But, barring damage from cosmic rays or some unforeseen occurrence, solar batteries will just keep on operating — perhaps forever!

In addition to their use in satellites, solar cells are used for radio transmission in remote locations and as warning beacons. Clocks and radio receivers operate 24 hours a day, using solar cells coupled to storage batteries. The self-charging flashlight is another successful use of solar cells.

Solar-cell panels of many square feet are available commercially for tasks that justify the high initial cost. Solar cells are not cheap, even though silicon is one of the most plentiful elements. To be suitable for solar cells, the silicon must be ultrapure. This means that the raw material to make a sun battery costs more than one hundred dollars a pound, and the manufacturing process is expensive too. It's helpful to remember, though, that first cost is total cost.

With a little background, we are now ready to build our own solar power plant. The model shown in the drawings and photograph uses Hoffman 2A silicon cells and an Aristo-Rev motor. Other cells of equal output will be suitable. If this size battery is out of your reach financially, you can buy a smaller battery and motor. Check the suppliers listed and radio and hobby supply houses.

As an alternative, selenium cells may be used. According to International Rectifier Corporation, which makes them, a single B2M battery will run one of the tiny motors available commercially.



CIRCUIT FOR ROUND-THE-CLOCK OPERATION

SOLAR MOTOR

Materials

Edmund Scientific Corporation, Barrington, New Jersey
Aluminum foil
Electric motors
Solar furnaces
Solar stills
Solar batteries

After choosing your batteries and motor – or while you are waiting for them – get to work on the stand and motor support. Cut the base and the two triangular supporting pieces from 1/4-inch wood. Balsa wood was used in the power plant illustrated because it is easy to work with.

If you are using a motor other than the one shown, make the circular cutout in the supports to fit *your* motor. Glue the supports to the base and let dry. This mounting will accommodate a 3-inch propeller and should be adaptable to almost any project you have in mind.

When the glued joints are thoroughly dry, insert pins or small brads in the supports as shown and strap the motor in place with rubber bands. The propeller may be added now, or you may substitute a small pulley or gearbox arrangement.

It is safer to buy your solar cells with leads attached. If it is necessary to solder the leads to the cells, follow the manufacturer's instructions with extreme care. If the temperature goes too high the factory-applied solder will melt off, and this is not only embarrassing but expensive!

Notice that the cells are wired in series. Since each cell has an output of approximately .5 volt, connect enough cells to provide sufficient voltage to operate the motor. Group the cells to fit on the base and protect them with a rigid plastic cover taken from a pinbox or similar container. A drop of model airplane cement at each side of the cover will hold it securely in place.

All that is necessary to complete the job is to solder the free leads to the motor clips. These clips are easily removable and make the soldering operation quite simple, especially if you have just soldered your own leads to the solar cells. Replace the clips on the motor, making sure the brushes are properly aligned, and the solar power plant is ready for action.

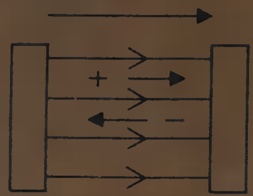
NASA

Tiros weather satellite powered by thousands of solar batteries.

SILICON CRYSTAL

Light is absorbed in a silicon crystal by liberating free-to-move negative charges, called electrons—and free-to-move positive charges, called holes.

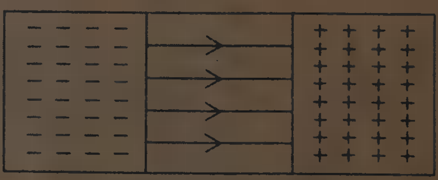
ELECTRIC FIELD



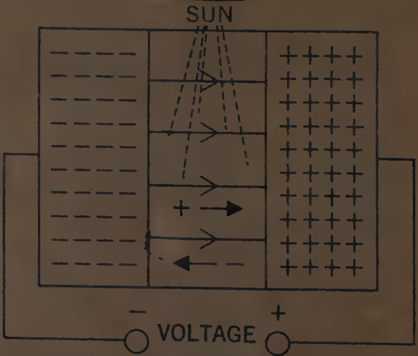
An electric field exerts a force on charged particles causing them to move if they are free. The force moves holes in one direction and electrons in the opposite direction.

SILICON P-N JUNCTION

ELECTRON RICH n SILICON | BARRIER OR ELECTRIC FIELD | HOLE RICH p SILICON



In a thin barrier at the junction between an electron-rich n-region and a hole-rich p-region in a silicon crystal, a strong built-in electric field exists which keeps the electrons in the n side and holes in the p side.



When light is absorbed, liberating electrons and holes in the barrier region at a p-n junction, the built-in electric field forces the holes into the p-side, making it positive, and the electrons into the n-side, making it negative. This displacement of the newly freed charges causes a voltage to appear between the ends of the crystal, a voltage that is a source of electrical power. Thus light energy is converted into electrical energy.

HOW THE SOLAR BATTERY WORKS

Place the assembly in the sunlight; the propeller should immediately begin to spin. On a bright day it will really "rev up." When you demonstrate your solar motor to friends, they will *oh!* and *ah!* and then suspiciously look for the dry cells you must have hidden somewhere.

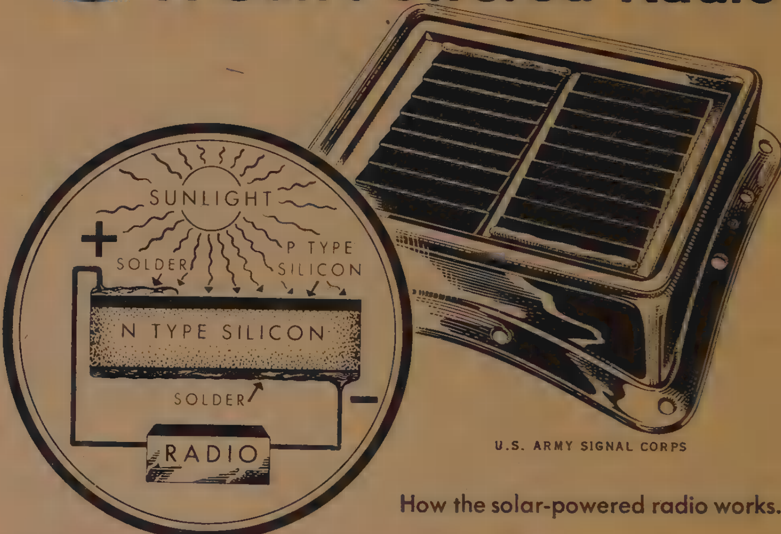
The light from a lamp will power the sun motor too – not as well as bright sun, of course, but quite satisfactorily. Just don't get too close to the bulb, because heat higher than 185 degrees F. can damage the solar cells.

Uses for the sun motor are limited only by the scope of your imagination. The spinning propeller suggests a realistic display of a scale model plane – or maybe a prop-driven car! Conventional model autos, trains, and boats can all be operated by the sun. Window displays that normally use dry cells would be a good place to use sunpower. Put your brain to work and come up with more ideas that will run on sunlight.

The bane of the solar enthusiast is the cynic who smilingly asks what happens when the sun goes down. With our heat projects we didn't have much of an answer, but in the realm of the photovoltaic converter the story is different. With the proper setup we can go right on operating after dark. The answer lies in the storage battery.

The circuit shown on the drawing is presented as an idea of what can be done to provide standby power. Actual solar cells, secondary batteries, and motors used will, of course, depend on the application you want to make. The principle is simple: the solar cells charge the secondary battery with surplus current during the day. When needed, this reserve supply is called on and we smile back at the cynics, while we use *stored* sunlight!

8 A Sun-Powered Radio



How the solar-powered radio works.

IN this chapter we will build a radio powered entirely by sunlight, or by artificial light for indoor and night-time use. The general principle, of course, is the photo-voltaic process described in the last chapter. Our radio makes use of a selenium cell that can be purchased for as little as a dollar and a half. A silicon cell will work even better.

The recent introduction of transistors and improved solar converters has made possible radio reception, and even transmission, with no power other than sunlight. In 1955 a message was sent from a sun-powered transmitter and picked up on a sun-powered receiver, operated by radio hams. Our armed services have developed walkie-talkies, helmet radios, and emergency equipment powered by solar energy.

More recently, sun-powered transmitters have been sent aloft in satellites. Sun batteries also power remote radio installations and harbor warning-beacons by charging storage batteries for round-the-clock operation. The advantages are obvious. No power lines are necessary, and solar batteries last indefinitely.

The practical application of solar-powered radio has passed far beyond the simple receiver described here; however, the easy-to-make little radio nicely demonstrates the use of the solar battery as applied to electronics. The interested reader will find a large amount of material on more advanced projects in books such as *Solar Cell and Photocell Handbook* published by International Rectifier Corporation, and in mechanical and electronics magazines.

Materials

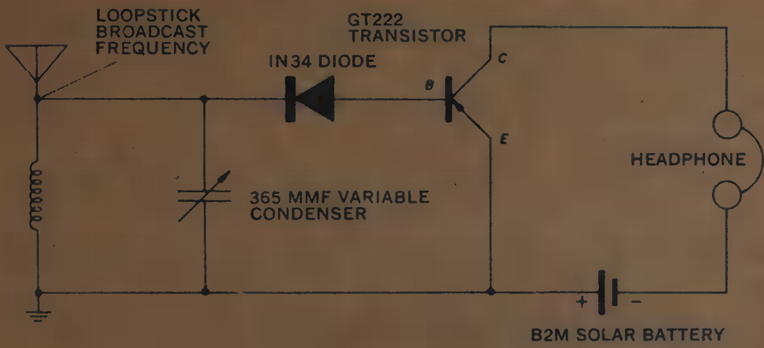
1 B2M solar battery (or substitute)
1 Audio transistor
1 IN34 diode
1 365 MMF var. condenser
1 Antenna coil — broadcast
1 Headphone — 2,000 ohms or more
1 Plastic box
2 Phone jacks
2 Binding posts
1 Terminal board
4 Rubber feet
No. 24 hook-up wire, antenna wire, and 6-32 screws, nuts, and washers as needed

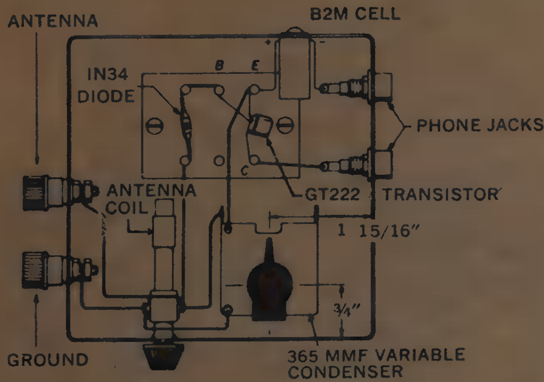
Most of the parts for the radio may be purchased at your local radio wholesale house or from a mail order firm. You will be able to buy from the wholesaler if you tell him you are an experimenter and describe the project. The plastic case – a sandwich box or similar container – can be bought at the dime store. Prices will vary somewhat, but will be between five and eight dollars for all the parts, including the earphone. In case the radio parts specified in the list of materials are not available, the clerk will be able to provide equivalent items.

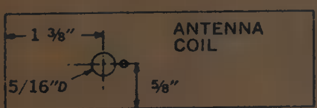
No attempt has been made to miniaturize the assembly of the radio, and the beginner will find it easy to put together. The various parts are spaced for easy connection of wires and ample room for the soldering iron. If you desire, the radio may be squeezed into a box about one quarter the size of that shown. A miniature condenser much smaller than that used here is available at some of the mail order houses, and the terminal board can be eliminated. But such changes are left to those with some previous experience with radio work.

Whichever plan of attack you decide upon, have all the parts on hand before you start work. You'll find that you can complete the radio in an evening, and start enjoying it immediately – using a reading lamp to substitute for the sun!

Our first task is to drill all the mounting holes in the plastic box, which will house the radio. Check the diameter of the phone jacks, binding posts, antenna coil, and condenser at the points where they go through the plastic, and drill holes of the proper size. For the larger holes







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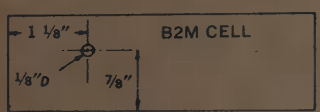
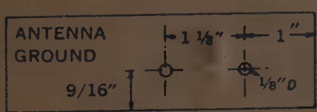
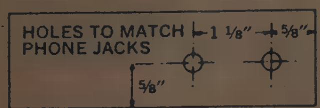


BACK



LEFT



RIGHT

SUN-POWERED RADIO

it is a good idea to drill a pilot hole first and then enlarge it to the correct size. Be careful not to crack the plastic. If you do not have a large enough drill, use a round file to do the job.

Because the condenser shaft must protrude through the plastic cover, we will drill this hole first. Locate it according to the dimensions on the drawing, unless the condenser you are using is of much different size and shape. Place the condenser in the box and put the lid on it. Now turn the box over carefully, keeping the condenser properly located, and drill through the plastic and into the mounting holes in the condenser frame. This procedure ensures that all the holes will line up when it is time to assemble the radio.

Notice that the small hole drilled near the edge of the antenna-coil mounting hole must match the fitting on the coil. Use the metal mounting bracket included with the coil as a template to properly locate the small hole.

After all the holes are drilled, including those for the terminal board, clean up rough edges, remove chips from the box, and assemble the parts. Tighten the phone jacks and binding posts snugly, and use fiber washers with the 6-32 screws and nuts to protect the plastic. Snap the antenna coil into place and mount the solar battery with the glossy surface up.

With all the parts installed, we will do the wiring next. Follow the drawings carefully if you are not familiar with radio theory. The diode will probably be labeled with an arrow like the one shown on the drawing, or coded in some other way to indicate direction. The center

lead on the transistor is B, as shown in the drawing, and the lead closer to it is E. Make sure of the hookup of the diode and transistor and also that the sun battery's black wire goes to the phone jack.

Soldering the connections will, of course, give best results. However, since it is easy to damage transistors by overheating, you may want merely to wrap the lead wires around the posts of the terminal board. While not as good an electrical connection, this method does work and was used on the radio in the photograph. If you do solder the transistor in place, pinch the lead between the solder joint and the transistor with a pair of long-nosed pliers during the operation, to draw off surplus heat.

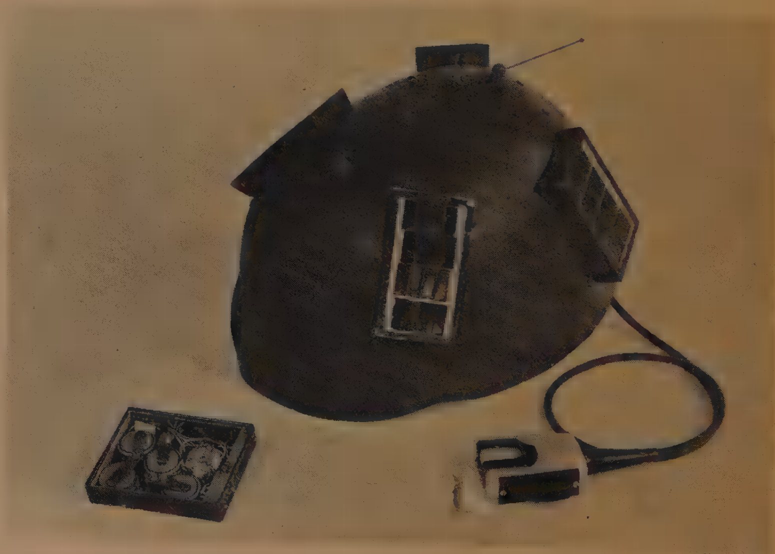
Now wipe up any excess soldering paste; check all joints and mounting screws for tightness. If everything

Solar radio operates indoors as well as out.

is in order, put on the plastic top and mount the control knobs. If you were unable to find a knob small enough for the antenna-coil adjusting screw, use the cap from a toothpaste tube as shown in the photograph. Drill a hole slightly smaller than the screw and twist the cap onto the shaft. To make the adjusting screw easier to turn, carefully bend the spring clips away from the shaft. Paint the cap black to match the one on the tuning condenser, and the radio is complete.

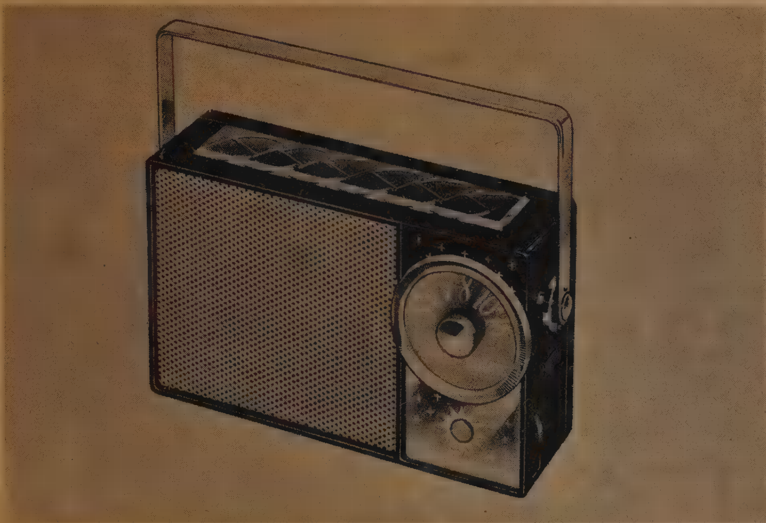
This book is not the place for a technical discussion of the theory of radio, but we can briefly trace the radio waves that come through the air and are converted to sound in our receiver with the help of sunshine.

Radio signals are picked up by the outside antenna and carried into our radio. From all these faint signals,



U.S. ARMY

Four clusters of solar cells operate the tiny two-way radio inside this helmet.


HOFFMAN ELECTRONICS CORP.

Hoffman portable solar radio. Plastic strip on top encases sun batteries.

the desired station is selected by adjustment of the tuning condenser and the antenna coil. From this tuning circuit, the chosen signal goes through the diode "detector," which passes only the portion of the signal that we are interested in. This "audio" signal, still very faint, goes next to the transistor where it serves to trigger proportional, but much greater, amounts of power from the sun battery. This amplified audio signal activates the earphone and is the music or the news broadcast we hear.

So much for theory; now to see how well our solar radio works. Attach an outside antenna to the proper binding post and a ground wire to the other post. The longer the antenna, the better, although the radio shown performed well with about 10 feet of wire and brought

in several stations. It did a better job when connected to the TV antenna.

If you live many miles from the nearest radio station, you will have to use a long antenna. In extreme cases it may be necessary to increase the power of the radio by adding one or more solar batteries, connected to the original in series – that is, red wire soldered to black. This increases the voltage of the power supply.

In most cases the radio will bring in several stations nicely in bright sunlight. Use the tuning condenser to select your program and sharpen up the adjustment with the tuning coil. To fancy up the radio, add a broadcast dial, with appropriate frequency numbers drawn in just as on a large radio. You've probably noticed that there is no on-off switch, but don't worry about leaving this radio on all the time. There's nothing to wear out, and the power is free!

At night, or on very cloudy days, you can tune in your favorite programs simply by placing the radio under a lamp. Don't place the solar battery so near the bulb that it becomes heated, as this may damage it. This should not be a major problem; satisfactory operation can be obtained at a safe distance from the lamp.

That's the solar radio. Good luck building and using it; with care your set should give a lifetime of service. If the electronic side of solar energy appeals to you, there are many interesting projects you can work up: a code practice oscillator, for example, a continuous wave (code) transmitter, or even a portable receiver that requires no external antenna.

9 The Sun Tomorrow

HOPEFULLY, *Solar Science Projects* will not serve merely as a blueprint for fun things to do with the sun. More important is the need for us all to realize the great potential in solar energy beyond our present use of it. Above all, the sun represents an abundant supply of energy in a form that is pollution-free, contains no harmful radiation, is silent, and non-toxic. At present, sunlight is even free! Solar stoves cook without smoke or ash; solar stills produce no thermal pollution or air pollution; solar electricity is produced with no radioactive byproducts, no moving parts, and no need for fuel.

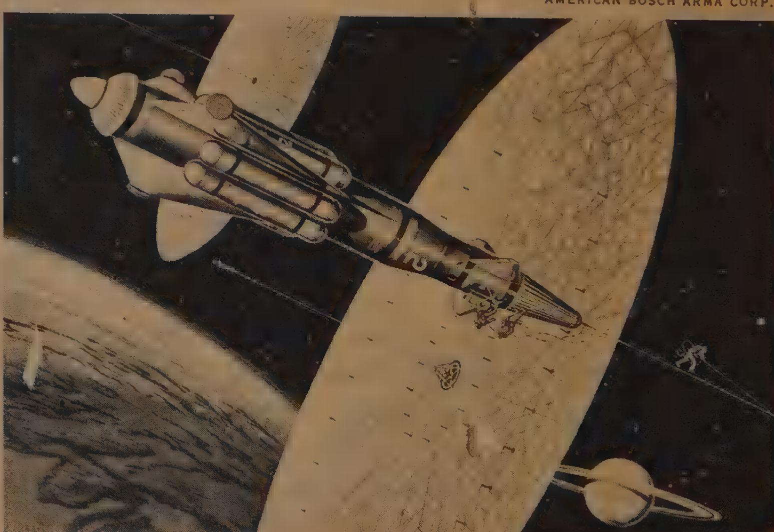
For a world beset by problems of pollution, fuel shortages, nuclear dangers, and noise, solutions may lie in the sunshine that blesses most of the world. Yet presently we use only a tiny fraction of the sun's energy—the rest is wasted as far as any practical use is concerned.

Many people suffer from the cold, and solar energy can warm their houses. It can even cool their houses too! Enough sunshine showers down on our roofs not only to heat our homes and cool them, but to provide all the electricity we need for lighting, utilities, and so on.

Solar energy can provide fresh water (it does this now, of course, on a global scale, but man could make more use of it in problem areas). Even in the growing of food, the greatest use we make of the sun, there is tremendous room for improvement since plants use only a fraction of one per cent of the sun's energy in the marvelous process of photosynthesis. A new generation of solar scientists may find ways to grow more food per acre, and thus help to feed the exploding population of our crowded Earth.

Artist's concept of spaceships pulled by solar "sails." (Frank Tinsley drawing.)

AMERICAN BOSCH ARMA CORP.



Just the Beginning

Far from being the last word on the subject of solar energy, this book should only serve as a starting point for those interested in solar energy applications. Solar science still has room for enterprise and imagination. You can take it from here and develop projects of your own.

Chances are one phase of solar work appeals to you more than the others. If you're a radio or electronics fan, you probably will spend more time on Chapters 7 and 8. Why not try a sun-powered transmitter or maybe a receiver with a loudspeaker instead of the earphones used in the basic sun radio?

If power from the sun strikes your fancy — and watching the prop on the simple sun motor spin hits deep if you have some imagination — design and build yourself a more powerful electric motor than the one presented here. Try a steam engine with a solar-fired boiler. Even solar turbines and hot air engines have been made, some of them a long time ago. Recent work in this field is described in publications like those of the Solar Energy Society, about which we shall say more shortly.

Optics, a fascinating field, is directly related to solar energy. Starting with the Fresnel lens in the chapter on the solar furnace, see what other things you can do with it. Try compound arrangements of other types of lenses. An experimenter might combine the Fresnel lens with the solar cell, thus focusing more light onto the surface for a greater output of current. The limiting factor here is the temperature generated at the surface of the cell. If this goes too high, the solder will melt, or

the converter material itself may be harmed. You might try to develop a tracking mechanism to keep the lens focused properly.

The chemist will be interested in the solar still, or perhaps a sterilizing device using sun heat. One researcher realized that there is a loss of efficiency in the collector when water condenses in drops on the glass surface. His solution was a special nitric acid treatment which permitted the moisture to condense in a film instead, resulting in greater transmissivity of sunlight. Another solar project is that of algae culture, thought by some scientists to be an answer to food shortages for our rapidly increasing population.

For the experimenting gadgeteer, solar collectors can be made from discarded auto headlights, their parabolic shape being perfect for this purpose. A fire starter can be made from a flashlight reflector. Kindling paper or wood is held at the focal point and presto – a fire, courtesy of the sun.

At the other extreme is the large parabolic reflector made from surplus radar antennas or other appropriately shaped items. One of these would make a dandy cooker or furnace, but keep in mind that the focal point may be very small and very hot. Once burned is twice warned, but it's the hard way to learn. Be careful also not to burn the bottom out of the cooking pot!

The solar device that probably goes farther back than any other is the sundial. Although it is almost a curiosity now, it would be interesting and instructive to build one. Then go modern and put together a solar clock of the sun battery type.

The principle underlying our modest little water heater

will also serve a system that provides ample hot water for a house. Watch the papers for news of solar-heated homes that may be built in your vicinity. There are more of them being designed and erected each year. If you are interested in architecture, perhaps you already know how important the sun can be in proper heating. Some day it may be possible to cool a house with solar energy.

A variety of sun-powered space travel ideas have been advanced. One concept that is fantastic enough to make an ion motor seem ancient by comparison is called "solar sailing." This is traveling through deep space by unfurling a huge solar sail to catch the "wind" of photons!

Man may not take to the sea of space in a solar sailboat for some time, but he has already orbited the Earth and landed on the moon. Solar energy is used in a moon power station. Since the airless lunar surface receives more energy from the sun per unit area than does the Earth, such a system would be of value to moon voyagers.

Experimental work continues with thermionic, thermoelectric, and thermodynamic converters that take various approaches to the production of electricity. Such converters have applications in space — and also for stay-at-homes. Advances are described in *Solar Energy*, the journal published by the Solar Energy Society, and available at many libraries.

Proper use of solar energy can make the years ahead much brighter for mankind. How better to be "in tune with nature" than to use nature's primary source of energy — safe, clean, abundant energy. Perhaps these projects will stimulate an interest toward that goal. Meantime, have fun with the sun!

SUPPLIER FOR SOLAR SCIENCE PROJECTS

Edmund Scientific Corporation, Barrington, New Jersey
Aluminum foil
Electric motors
Solar furnaces
Solar stills
Solar batteries

TO LEARN MORE ABOUT SOLAR ENERGY

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12441 Parklawn Drive
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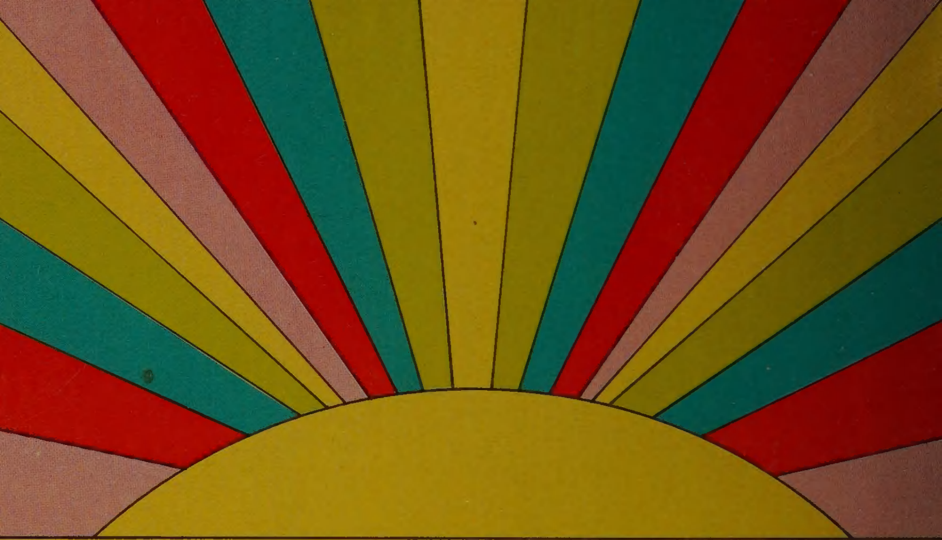

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7 Solar Energy Projects You Can Build and Use.

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